An Investigation on Task Interruptions and the Physical Environment for Human Performance

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An Investigation on Task Interruptions and the Physical Environment for Human Performance

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SUMMARY

Many dangerous or tragic events such as airplane crashes and medical errors are often the result of human errors, and these errors are often the result of a professional worker being interrupted during a critical task. Although their impact can be serious, the ways that interruptions are affected by the physical environment have rarely been examined in the study of architecture. This thesis investigates how the physical environment helps manage the interruptions by observing the process of medication administration by nurses in hospital units. Nurse shadowing observation data showed that the level of visibility of work areas in and around nurse stations significantly contributed to the number of interruptions initiated by others. This thesis concludes that the physical environment affects interruption events and discusses the design implications of observation-based findings and the potential impact of the physical environment on major clinical errors. As for future directions for investigation, this thesis recommends that interruptions become a more prominent subject for consideration in architecture, and the physical environment become a subject for analyzing interruption and performance in human factors and health care.

CHAPTER 1

INTRODUCTION

In this dissertation, I review how the physical environment contributes to the management of interruptions for human performance, using observations of the medication administration process by nurses in a hospital. Many dangerous or tragic events such as airplane crashes and medical errors are the result of human errors, and these errors are often the result of a professional worker being interrupted during a critical task. Although the impact of interruptions can be serious, critical tasks and the ways that interruptions are affected by the physical environment have rarely been examined in the study of architecture. Therefore, the goal of this investigation is to assess the quantitative measurements of the physical environment such as visibility and physical accessibility for predicting the number of interruptions along the path of nurses' medication administration trips. For the measurement, I utilized a methodology called "i-Partition," that defined areas by the physical properties of space such as visibility so that the defined areas can better reflect spatial characteristics for interruption events, which is further explained in Chapter 4.

In Chapter 1, I describe a multidisciplinary approach for understanding interruptions and their impact. The significance of interruptions is also discussed by explaining how human error might occur due to interruptions' impact on human memory. Using this multidisciplinary approach, in Chapter 2, I examine the social and physical environment in which interruptions and related interactions occur to understand different theories on the effects of interruptions. For example, I discuss theories that focus on positive communication versus those that seek to eliminated unwanted interruptions. Here it is understood that interruptions should be reduced to prevent adverse events during critical tasks such as medication administration in health care because of the potential for medical errors. In Chapter 3, I examine other studies to understand nature of interruptions and discuss the seriousness of the interruptions' impact in health care.

The negative impact of interruptions might be reduced by managing them, and the role of physical environment in that management is the subject of hypotheses in Chapter 4. These hypotheses are then tested by observations of nurses' medication processes in intensive care units. Based on these observations, I measured physical characteristics such as visibility and accessibility of paths that they walk while performing the process, and counted the number of interruptions. In Chapter 5, I analyze the observation data, with the result being that visibility was associated with interruptions but not accessibility. In the final chapter, I discuss the different ways that each of the visibility and accessibility measures might be used to predict interruptions or interactions. The nature of interruptions observed and design implications are also discussed in the last two chapters, and directions for future research are suggested.

1.1 A Multidisciplinary Approach

In this thesis, I aim to address interruption and interaction events from multiple perspectives based on studies in architecture, management, and human factors. To better understand and manage encounters, I examine their social contexts to find clues for different perspectives on the effects of encounters. I use rigorous methods drawn from architectural studies for measuring the physical environment, and use a specific part of a task, as in some human factors studies, to find the effects of the physical environment.

Talking, and other types of encounters with people are natural human activities. However, interpreting the effects of encounters varies across fields, as do methods for studying how these encounters happen in the physical environment. These tend to reflect that most architectural studies and some management studies view the encounters as positive, productive activities for social relationship development and knowledge sharing, while some management and human factors studies view certain human encounters as counter-productive, a fact that will be explained further in Chapters Two and Three. For example, in management or organizational studies as well as architectural studies, the propinquity perspective claims that decreasing proximity and removing barriers encourages more encounters between people, and this can result in productive communication and learning for people involved (Allen, 1977; Boutellier, Ullman, Schreiber, & Naef, 2008; Rashid, Kampschroer, Wineman, & Zimring, 2006).

On the other hand, the privacy perspective argues that people interact more comfortably when they can control the situation, and the existence of barriers actually reduces unwanted interruptions and distractions (Fried, Slowik, Ben-David, & Tiegs, 2001; Hatch, 1987; Oldham, et al., 1995; Zimring, Weitzer, & Knight, 1982). Furthermore, human factors studies view encounters as critical interruptions to tasks. For example, interruptions to preflight checks are found to affect pilots' performance (Healey, Sevdalis, & Vincent, 2006) and have contributed to airplane crashes (Monk, et al., 2008). In nuclear power plants, more than 15% of all shutdowns were associated with interruptions (Edwards, et al., 2009). Further, in health care, the incidence of medication administration errors can go up by 60% when nurses are interrupted (Biron, Lavoie-Tremblay, et al., 2009).

Therefore, we have contrasting views regarding encounters in determining their effects on human performance. One of the physical settings that reflects the importance of these contrasting views is healthcare or hospitals. For example, nurses have to accurately administer medications without interruptions while they also have to communicate with the health system and relay information to other clinicians. However, while some attention has been paid to communication (Rashid, 2009) and patient monitoring (Shepley & Davies, 2003; Sturdavant, 1960) less has been paid to interruptions in these studies and in the design of hospital units. Studies might need to focus on encounters at the task level and in a specific setting to better understand these two contrasting views on encounters (Fayard & Weeks, 2007; Oldham, et al.,

1995) because the contrast might be due to a lack of understanding of encounters in terms of social environment factors such as culture, task type, and job position. This is discussed in the Chapter Two.

In addition to understanding the context of encounters, we can benefit from the different methods used in various academic fields. Human factors studies have critical views on the interruptions of tasks, and use rigorous methods such as task analysis, which describes human involvement in processes or a system in detail through direct observation (Wolf, et al., 2006). This allows us to examine how human capabilities and activities support achieving the goals of an organization or system (Kirwan & Ainsworth, 1992). Therefore, the task analysis method helps us evaluate and clarify the impact of encounters on human performance. Architectural studies also use direct observation methods but are often focused on documenting interaction itself (Rashid, et al., 2006). They do not directly examine interactions through analysis of the task process involved. Management studies mainly relied on surveys rather than direct observation (Oldham & Brass, 1979; Zalesny & Farace, 1987).

Although architectural studies might not have been thorough in examining social context and work processes, they have developed rigorous physical environment measurements such as the Depthmap program in space syntax studies (Turner, 2004). This program analyzes and quantifies physical characteristics such as visibility and accessibility of floor plans by assigning small tiles for values as small as a foot square tile or smaller regardless of office or building types, which renders various structure types comparable to each other for the given characteristics such as visibility. In fact, studies in management have described or identified the physical environment as open-plan, partitioned, or cellular offices. However, for example, there is no clear definition of open-plan office, every open-plan office can be different, and it has been challenging to differentiate various open-plan offices for management studies that assigned a single layout type for the entire floor such as open-plan or cellular. Someone near the walls, for example, in the corner of an open-plan layout might have quite different barriers compared to someone in the center of the same floor (Greg R. Oldham, Cummings, & Zhou, 1995). In addition, quantitative comparison is difficult between different types of office layouts. These issues are resolved in architectural studies because they use the measure of the physical characteristics such as accessibility and visibility values that are assigned to the small tiles on the floor plans regardless of layout types (Peponis, et al., 2007; Rashid, Wineman, & Zimring, 2009).

1.2 Interruptions and Performance

1.2.1 Significance

People tend to forget to do things. They especially do so when we are distracted or interrupted and might forget to send a note or not remember to make a call, especially when they have to do unplanned or unexpected things such as picking up a phone call from a friend or talking with a co-worker whom they happen to see. For most people, forgetting to do things or getting distracted and interrupted is a normal part of life, and it does not cause serious problems. However, for others such as nuclear plant managers, pilots, or doctors, whose work process requires them perform tasks that are critical or complicated, the consequences of forgetting might be dangerous or even fatal.

Studies show the negative impact of interruptions on performance in aviation (Dismukes, Young, & Sumwalt, 1998; Loukopoulos, Dismukes, & Barshi, 2001), driving (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009; Monk, Boehm-Davis, & Trafton, 2004; Strayer & Drews, 2004, 2007; Strayer, Drews, & Crouch, 2006), nuclear power plants (Edwards, et al., 2009), laboratories (Monsell, 2003), and hospitals (Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). In 1987, for example, an airline crew was repeatedly interrupted by various tasks and runway assignments from a control tower while preparing to take off, and they failed to see that the aircraft's flaps were not set to the takeoff position. They did not complete the checklist that would have prevented them from leaving them in the wrong position. Shortly after they took off, they crashed killing all but one person (Dodhia & Dismukes, 2009). In another case study, an intensive care unit, five out of six observed patient hazard incidents were immediately preceded by task interruptions (Drews, 2007), and medication errors in a pharmacy increased sharply with interruptions and distractions such as telephone calls (Flynn, et al., 1999)

1.2.2 Human Factors; Interruptions and Working Memory

The accidents and errors in job performance mentioned above might be a result of interruptions because we can experience difficulties in reconstructing the interrupted task. We may for example fail to resume a task in a timely manner and, as a result, commit errors after being interrupted (Dodhia & Dismukes, 2009; Monk, et al., 2004). A prospective memory task is created when an individual has to reconstruct an interrupted task without an explicit alert. Prospective memory uses some of a person's limited working memory capacity. Thus multiple interruptions can exhaust working memory, potentially leading to errors in the interrupted tasks.

In the event of an interruption (Figure 1.1), our memory follows a particular pattern. First, we recognize the presence of an interruption, the "interrupt alert" in Figure 1.1, such as a phone call or when we are aware of someone's approaching the office door (Dodhia & Dismukes, 2009). When an interruption occurs, we disengage from the existing task, try to figure out what the interruption is, and decide whether to postpone the original task or switch to the new task. One's divided attention at this moment might increase the memory load (Dodhia & Dismukes, 2009; Grundgeiger, Sanderson, Jenkins, & Leane, 2008). If we have switched tasks, we now have the prospective memory load of remembering to resume the original task at some point in the future.

The long duration or heavy demand of the interrupting task might overload working memory capacity, possibly resulting in a failure to remember the original task (Monk, et al., 2008) (Figure 1.2). In order to reduce the memory load and reduce the risk of subsequent error we commonly employ several strategies. We may finish a subtask (e.g. complete writing the current sentence when writing a letter), create memory aids (e.g. place a bookmark or write a brief note describing the next step), or simplify the goals of the current task. These coping strategies may not always be employed and may not always be successful (Altmann & Trafton, 2002; Bohand, et al., 2009; Dodhia & Dismukes, 2009).

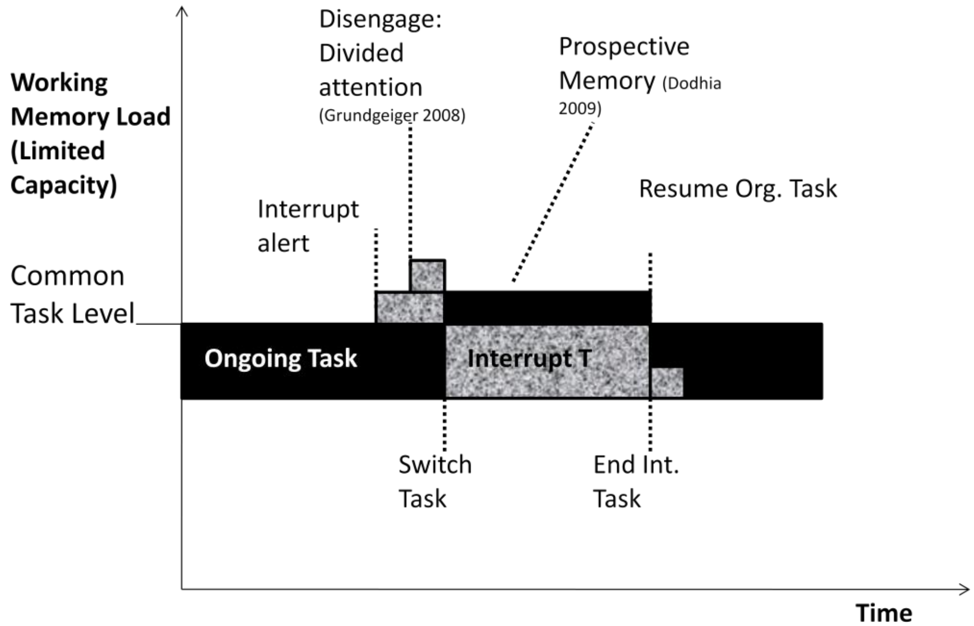


Figure 1.1: Interruptions and Working Memory Load Increase

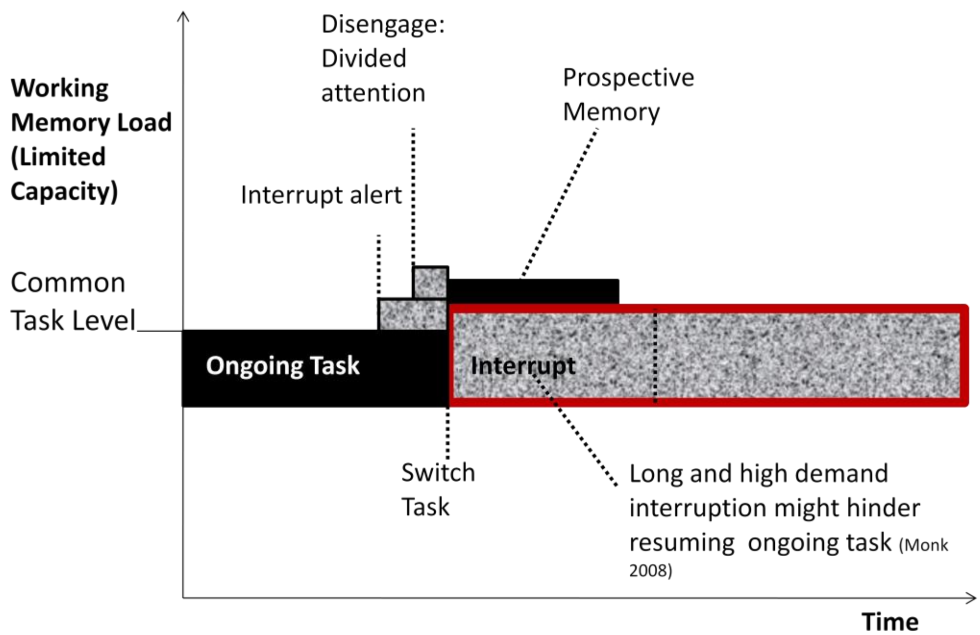


Figure 1.2: Long and High Demand Interruptions and Failed Resumption of Original Task

CHAPTER 2

SOCIAL AND PHYSICAL ENVIRONMENT OF ENCOUNTERS

2.1 Introduction

2.1.1 Aim

This chapter reviews the research literature to find out how the physical environment affects chance encounters and how the effects of encounters are different in certain social environments. The social environment is examined because two different main views have emerged on the effects of chance encounters: some studies viewed chance encounters as productive interactions for communication while the others viewed them as counter-productive interruptions. Even though we desire both interactive communication and the prevention of unwanted interruptions for most tasks, few studies have examined the context, especially social environmental factors such as roles and tasks, to help determine which view we should apply when we design a physical environment (Fayard & Weeks, 2007).

Therefore, this review of the social environment is done to determine when, how, and for whom the physical environment should support one of the two or both views (Allen, 1977; Zalesny & Farace, 1987). In the discussion and conclusion of this chapter, I identify the limitations of the perspectives and methods of the studies across academic fields and show how these limitations might be overcome by a multidisciplinary approach to examining the effects of the physical environment.

2.1.2 Background

Studies have rarely examined the social characteristics of the physical environment from both perspectives across different settings and fields. If this lack of a coherent understanding and efforts could be overcome, the design of buildings for critical functions such as medication administration in hospitals may be less conducive to interruptions (Westbrook, et al., 2010) while encouraging informal interactions for sharing and creating knowledge (Boutellier, et al., 2008). Rashid (2006) points out that although he and his colleagues found that visible co-presence predicts encounters between people, spatial variables did not consistently correlate with encounters. Rashid also argues that the spatial layout itself can not sufficiently explain encounters unless one also considers the attitudes (or "culture"), the programs, and the policies of an organization.

Technologies are available now that might reduce the incidence of mistakes caused by interruptions in some specific situations. The use of barcodes and scanners, for example, might reduce the negative impact of interruptions during medication administration by positively identifying the correct patients. But interruptions affect a rather broad range of overall activities and tasks in a work environment because they are social phenomena. In fact, if interruptions can be identified that affect a specific task such as medication administration in hospitals, it is not likely that the rest of the tasks of the health care worker are free from interruptions either, unless specific policies or regulations are strictly implemented to prevent them. As a strategy to shape the social environment, the physical environment might be effective in managing interruptions and interactions to support goals of organizations (Bafna, 2003; Hillier, 1996a; Oldham, et al., 1995).

2.2 Review Methods and Scope

A literature search was conducted in Web of Science, PsycINFO, and Academic Search Complete database using keywords including but not limited to: interaction, interruption, design, layout, and office. In addition, I went through the reference section of each study that was found and also conducted a reverse citation search, looking for studies that cited each study that was found. Since I am looking for descriptions of how the physical environment affects chance encounters, assessing the quality of studies that examined the impact of the environment on performance, satisfaction, or other human reactions might not be very meaningful. Instead, I described the methods and findings of each study and findings relevant to this thesis in a summarized table format (Appendix A.).

There are two streams of thought on the subject of chance encounters that are affected by the physical environment (Boutellier, et al., 2008), depending on whether the interruption event is viewed as productive (Boutellier, et al., 2008) or counter-productive (Oldham, et al., 1995). This review is inclusive of both types of chance encounters because the effects of the physical environment such as visibility and accessibility might have very similar mechanisms (Rashid, Wineman, & Zimring, 2009; Westbrook, et al., 2010; Wineman, Kabo, & Davis, 2009) The review of academic literature was not limited to buildings of certain types, but it so happens that many studies have been done in office settings. The effects of interruptions on factors such as performance and satisfaction levels were not always examined by studies that focused on how the physical environment affected encounters.

2.3 Results

2.3.1 Interruption or Communication: Different Views

A review of the literature revealed two main, comparable theoretical perspectives; socio-relational and socio-technical, relevant to the role of the physical environment (such as walls) in work settings (Oldham & Brass, 1979; Zalesny & Farace, 1987). From the socio-relational perspective, the physical environment serves as a catalyst for communication and social networking (Hillier, 1996b) while from the socio-technical perspective the environment serves as a protector of privacy (Oldham, et al., 1995). In fact, we can draw two different technical assumptions about chance encounters; that the former viewed them as productive interactions while the latter viewed them as interruptions.

2.3.1.1 <u>Social Relations Perspective</u>

One group of social relations perspective studies considered chance encounters as an opportunity to organize and share multiple pieces of knowledge from different specializations, especially in research and development (R&D) departments(Boutellier, Ullman, Schreiber, & Naef, 2008; G. R. Oldham & Brass, 1979). The basic idea is that more interactions between people create greater attraction and this is a pre-condition for high performance, such as teamwork performance (G. R. Oldham & Brass, 1979). Interactions also provide performance feedback to employees and help them develop friendships and opportunities to resolve interpersonal conflicts (Oldham & Brass, 1979). Allen (2000) points out that chance encounters are needed where communication for creativity is desired. He lays out three types of technical communications for product development engineers. The first type is communication for coordinating work that helps teams or sub-teams be aware of each other’s work, while the second communication type is for keeping up to date with knowledge that is dynamic and under development. The third is interaction for creativity, which is the most unpredictable and difficult to manage among the three types because it mostly happens during chance encounters

Studies suggest that linking disconnected people into social networks and enhancing connections between people who are already connected are significant predictors of innovation, and this linking can be associated with the spatial environment (Wineman, et al., 2009). In addition, most office work is considered as “knowledge work” and collaboration and teamwork are an essential part of office culture (Rashid, et al., 2006). Communication can also reinforce organizational culture by helping raise awareness of what is happening around an office and by spreading knowledge and skills (Rashid, et al., 2006). With this in mind, designers would aim to increase communications opportunities by manipulating the physical environment, such as office layout (Rashid, et al., 2006).

Unplanned encounters that are prompted or enabled by spatial configuration might provide communication and social networking opportunities, improve productivity, and create or reinforce culture (Peponis, et al., 2007; Wineman, et al., 2009; Wineman & Serrato, 1998). The positive evaluation of unexpected encounters was also done by some crowding and occupational psychology studies where open-plan offices, it is claimed, support communication leading to improved morale and productivity.

The positive view of the open-space layout in the field of architecture has been best represented by the famous architect Mies van der Rohe and his works. His vision for open space was first shown in 1929 when he designed the German pavilion at the International Exposition in Barcelona. The fluid space concept was achieved with internal walls that do not support structure and can be moved around. In 1940s, he designed the Farnsworth house that had a single room subdivided by partitions and enclosed by glass. He started applying his open flexible space concept to much larger scale buildings in 1950s when the development of structural systems enabled large open spans with few structural walls or columns. He designed his masterpiece skyscraper, the Seagram building, in 1954, a demonstration of the idea that an open view creates communication opportunities, and this open office layout type became popular in architectural practice following his early design (Oseland, 1999).

2.3.1.2 Socio-technical Perspective

On the other hand, from the socio-technical or “social interference” perspective, a space with physical boundaries such as walls and partitions provides private areas where people can share personal and work-related information and develop friendships, and in this situation it is easier for them to provide performance feedback to each other. In these spaces, people are protected from external intrusions. Boundaries protect people from unwanted interference and provide a level of privacy, thus people can have more control (Oldham & Brass, 1979). In addition, if boundaries are properly placed, people can better identify their tasks and the tools needed to complete those tasks. Employees perceived less impact on their work compared to when they saw the overall work process in open-plan offices (Oldham & Brass, 1979).

The studies that support the socio-technical perspective argue that boundaries provide space for meaningful, quality interactions and improve work performance. People experience more unwanted intrusions when there is less architectural protection such as partitions (Archea, 1977; Oldham, et al., 1995; Yildirim, Akalin-Baskaya, & Celebi, 2007) or when they are in open-plan offices (Oseland, 1999; Sundstrom, 1987). Hatch (1987) found that professional-technical workers in workspaces with higher partitions spent more time in work meetings and working with others than those in spaces with lower partitions, and concluded that enclosure supports interpersonal and group interactions. People also could concentrate on tasks better in private offices compared to open-plan offices, and building friendships with other employees became more difficult when they lost private offices.

Some studies (Desor, 1972) identified no positive effects of physical enclosure on satisfaction and performance, however, it is claimed that these findings, which are inconsistent with studies mentioned earlier, might have been affected by certain specific conditions such as different types and heights of partitions, job complexity and individual differences of the studies (Oldham, et al., 1995). Fried (Fried 2001) mentions that people with complex task or jobs might experience negative effects from interruptions in the work environment because their limited cognitive load is challenged when interrupted while working on complex jobs. Zalesny (1987) found that employees, especially those in managerial and professional positions, felt deprived of privacy when they were moved from traditional cellular offices to open plan offices.

2.3.2 Social Environment and Encounters

Most of studies have not singled out chance encounters as a matter of investigation and, as a result, my discussion here encompasses both planned and chance encounters. I aim to describe how differences in the social environment such as jobs and tasks might have led to different conclusions about chance encounters, such as whether they are considered productive or non-productive.

2.3.2.1 Task and Job Position

For research and development tasks, where knowledge is dynamic and staff need to keep up with changing and developing information, communication is encouraged or at least might be necessary, and chance encounters might be viewed as productive activities (Allen, 2000). For example in pharmaceutical companies, new technologies, revolutionary new ideas, and the dynamic business environment in drug discovery led to diversified approaches and increased levels of specialization, which brought attention to the importance of synthesizing and organizing knowledge as a significant creativity factor and a competitive edge for companies

(Boutellier, et al., 2008). Productivity in such companies is affected by communication that utilizes and creates new knowledge.

Innovation can come from weak ties between different groups that can be predicted by social network density (Wineman, et al., 2009). Wineman and colleagues (2009) showed that the integration of academic building floor plans and the level of accessibility between academic spaces is related to cross disciplinary co-authored publications that might be considered a measure of productivity for academic scholars. Educational pedagogy may also be supported spatial layout by increasing awareness and interaction of different academic fields and encouraging comparison or even competition among groups (Peatross & Peponis, 1995).

For white-collar office workers in corporate or government offices, views on chance encounters might be mixed depending on job position and tasks. Employees with managerial and professional positions compared to clerical positions felt more loss of privacy when they moved to open-plan offices from private offices (Carlopio & Gardner, 1992; Oldham, et al., 1995; Zalesny & Farace, 1987). They might have experienced a symbolic loss of their status and experienced negative effects of chance encounters without much architectural protection (Zalesny & Farace, 1987). In addition to symbolic effects depending on positions, complexity of tasks might influence the effects of chance encounters. In a lab study, individuals with a more complex task such as completing tax forms performed better when they were alone in a room compared to individuals with simpler tasks, such as clipping the forms, who performed best in a room with four people (Block & Stokes, 1989; Oldham, et al., 1995).

2.3.2.2 Social Designation of Space

In a study that examined interactions in photocopier rooms, Fayard and Weeks (2007) identified legitimacy of space use as a factor that affects interaction activities. In an organizational setting where everyone is supposed to make their own copies, workers feel comfortable to be seen by others waiting or talking in the photocopier room as well as using the copier. In addition, using a photocopier is not a very complicated task, so people are understood to be relatively available for conversation. Interaction between the user of the photocopier and someone who was waiting to use the photocopier seemed natural or even unavoidable. On the other hand, in an organizational setting where secretaries typically make photocopies for higher-level employees such as professors, seeing professors in the copy room might seem out of place even though all professors had obvious rights to use the space. Continuing discussions that started from a short chat in the photocopier room typically moved to private offices (Fayard & Weeks, 2007), suggesting that they were not seen as appropriate for the copy room. Social designation or the legitimacy of a space for interaction sometimes can be affected by the physical environment. In one study, employees did not seem to want to interact in the hallway of an open plan office because it might not have been comfortable talking with others next to work stations without barriers (Rashid, et al., 2009).

2.3.3 Physical Environment and Encounters

Many organizational studies examined the effects of design by comparing open-plan offices to private or other types of offices. While some of these studies considered the openness by design as a vulnerability to unwanted encounters, architectural studies such as space syntax studies viewed openness or accessibility and visibility as a support for chance encounters that became communication opportunities for socially generative phenomena.

2.3.3.1 Open-Plan Office

Primarily, many organizational and management studies compared performance between open-plan and cellular office workers. In the 1950s, the human relations movement encouraged open communication with fewer hierarchical barriers and employees' involvement in management decisions. This was partially achieved by having open-plan office layouts which were first adopted by a German company in 1960s. The open-plan office became popular, and most white-collar offices adopted the design by 1977 (Oseland, 1999). The popularity was partially because of operational cost, since it is known that open-plan offices cost 20% less to build and maintain than cellular offices (Hedge, 1982).

While open-plan offices became popular in industries, much research found disadvantages of the open-plan offices, which included increased noise and distractions, lack of privacy, and the inability to control the environment (Oseland, 1999). Sundstrom (1987) reviewed 13 studies of the open-plan office and found nine of them reported noise problems. Conversations and telephone ringing were the most distracting noises, mentioned by 50% of occupants, and this is probably because talking carries meaning and telephone ringing calls for an action to answer (Oseland, 1999; Sundstrom, 1987). Studies found that fewer enclosures and high spatial density were associated with low performance due to interruptions and distractions (Paulus, Annis, Seta, Schkade, & Matthews, 1976; Sundstrom et al., 1980; Worchel & Teddlie, 1976).

Other studies had the similar view that spatial characteristics such as fewer partitions, closer distances between workstations, and high spatial density have little architectural protection from unexpected and unwanted personal interactions or excessive sensory stimulation (Desor, 1972; Oldham, 1988; Oldham, et al., 1995). Archea (1977) also suggested that partitions limit such interruptions. Unwanted interactions that are prompted by spatial configuration might affect perceived personal control and ability to accomplish personal and performance goals (Oldham, et al., 1995). Yildirim et al (2007) also found that lower-partitioned office workers might lack visual and acoustic privacy and experience distractions and interruptions compared to higher-partitioned workers.

2.3.3.2 Accessibility, Visibility, Sound, Size, and Functions of Space

People can interact with each other directly when they can see each other, and studies, especially space syntax studies (Bafna, 2003) in architecture, have shown that better visibility, and spatial openness or accessibility was associated with increased person-to-person interactions in offices and other settings (Becker, Gield, Gaylin, & Sayer, 1983; Peponis, et al., 2007; Rashid, et al., 2006; Wineman & Serrato, 1998). Visibility and accessibility can be one mechanism that explains how people interact in the physical environment (Oldham, et al., 1995; Penn & Desyllas, 1999; Rashid, et al., 2009). Penn and his colleagues (1999) found a significant correlation between spatial accessibility and the mean frequency of encounters mentioned by other business units through observations in a utility company. In another study, government employees interacted more when they moved to a new office where accessibility was better than the old office (Rashid, et al., 2009). Another observation-based study found that visible co-presence was a significant predictor of interactions in government offices (Rashid, et al., 2006).

Spatial layout can affect the movement patterns of people, and this in turn affects chance encounters between them (Fayard & Weeks, 2007; Peatross & Peponis, 1995; Penn & Desyllas, 1999; Peponis, 1985). Studies found that the effect of a spatial layout on movement can be measured by integration, which is an expression of accessibility of an area from other areas. Penn and colleagues (1999) found more movement of people where the integration value is higher. Serrato and Wineman (1999) found that the most significant predictor of communication between research scientists in two differently designed labs was how well they were connected to a hallway that connected to other areas (integration) and how well these hallways were connected to overall building layout, which is represented by integration (Wineman, et al., 2009).

Integration might also describe functional centrality compared to physical centrality, as pointed out by Fayard and Weeks (2007). Functional centrality might not mean being located at the center of physical layout, but rather the way location connects the main circulation of people such as proximity to a main stairway, hallway, or elevator where everyone usually has to pass by the location when they come to the floor or the department. In addition to layout, features that a space contains, such as a photocopier, water-cooler, mail box, and fax, can affect the frequency of people's visits.

Visibility allows people to identify the presence of others across space so that they can call each other to start conversations. Another function of visibility is supporting the privacy of interaction by monitoring others' movement, so that people can adjust their conversation to manage what other people can see and hear (Fayard & Weeks, 2007). In this case, visibility contributes to control of the conversation. Sound also can play roles similar to visibility. It can help identify potential conversation partners or make people aware of the presence of those whom they might not feel comfortable to let hear the conversation. Studies found that semi-private space that supports both privacy and propinquity accommodated informal interactions well because it provided some privacy of interaction but still allowed people to locate others whom they can talk to. Fayard and Weeks (2007) also mention the size of a space in their study of encounters in photocopier rooms as a factor for interactions because the relatively small size of the space compels people to be close to one another in a way that might obligate conversation.

2.3.3.3 Spatial Analysis Technique

The strength of architectural studies in spatial analysis is mainly thanks to the UCL Depthmap Program that has been developed by Alasdair Turner at University College in London. This program uses a floor plan to make a map that shows how much one can see from various locations. The program lays out virtual square tiles on the floor plan, with the exception of the boundaries such as walls, and then it identifies other tiles that can be reached by straight lines from any given tile without intersecting the boundaries (Peponis, et al., 2007). The program can quantify visibility for a certain location or route that can be correlated to, for example, the number of interruptions. With this program, architectural studies found that overall spatial layout measures, such as spatial integration and density of the movement of people, help explain where and how frequently people interact (Penn & Desyllas, 1999; Rashid, et al., 2006). Spatial integration shows connectedness of a location to other locations, and the higher its value, the easier it is to get to its location from other locations (Bafna, 2003; Rashid, et al., 2006).

2.4 Discussion and Conclusion

2.4.1 Understanding the Social Meaning of Place

Rashid and his colleagues (2006) in a study that examined the impact of office layout point out that spatial layout might not be sufficient to explain observed interaction events, and that we need to look at the culture, programs, and policies of the organization. Lack of understanding of the social meaning of space might be the reason why we see conflicting views on rather neutral chance encounters by studies with either the socio relations or socio-technical view that was mentioned in Section 2.3.1. However, both views can complement each other in explaining the causes and effects of the encounters (Fayard & Weeks, 2007). Many researchers may have embraced only one of the two views because they mainly examined settings with similar social environments instead of examining settings of different types (Boutellier, et al., 2008; Peponis, et al., 2007).

This literature review found some understanding of the social environment, such as studies that examined tasks, job positions, and types of setting that might affect views on chance encounters. Socio-technical or privacy views on encounters might prevail more in some social conditions: those with more complicated tasks, uncertainty in tasks, and higher-level positions such as managerial and professional positions, compared to clerical positions. The social relations or propinquity view might prevail with simpler tasks or in research and development settings. In addition, various locations, even locations within a floor such as hallway versus a private office, might accommodate different views on encounters, because the accepted social designation of a space can be different according to an individual's role definition and the culture of the organization. These findings, however, are based on limited examples of studies and some did not describe the social environment enough to understand what tasks were done in a setting.

2.4.2 Description of the Physical Environment

Studies found that the distance between people and the density of people, for example, might affect the frequency of interactions (Allen, 1977, 2000; Fried, et al., 2001). However, these studies have not examined how accessibility or visibility, which might make distance and density less meaningful, might be affected by design of layout or individual workstations. In fact, enclosure details such as the number and height of partitions affect interactions and the satisfaction of employees as mentioned earlier (Oldham, et al., 1995; Yildirim, et al., 2007). Yet even these studies left out the effects of the overall layout of floor plans. In addition, Rashid and his colleagues (2006) point out that studies used different physical environment variables for comparison, such as the number and height of partitions versus open or closed doors of private offices, which makes it difficult to compare and describe space in terms of accessibility and visibility across different types.

While we can learn about the social environment and consequences of interactions from other fields, one strong lesson from architectural studies is the value of a more precise analysis of the physical environment factors such as openness or accessibility with a computer-based technique such as the Depthmap program. For instance, even though we use the term “open-plan office,” variations of the type are not well defined as mentioned in Chapter 1 (Rashid, et al., 2006). With Depthmap we can analyze a floor plan on the basis of quantified measures of openness and accessibility. In addition, while studies from fields other than architecture mainly discussed local characteristics of the physical environment for individuals, architectural studies such as space-syntax studies have expanded the topic to the impact of overall spatial layout and interconnectedness of multiple areas (Rashid, et al., 2006).

2.4.3 Suggestion for Future Studies

Understanding of the social and physical environment is needed for examining the effects of design on chance encounters and human reactions. As described earlier, depending on task, job position, and setting, the interpretation of chance encounters can vary from productive to counter-productive, and the design of space should consider the social environment. In addition, both the socio-relational and socio-technical views should be accommodated for space because we need both for communication and for the focused work we do. We can design specific areas with different combinations of both views. Some private offices might need a high-level of privacy while the others might not need it depending on tasks and roles of occupants.

CHAPTER 3

TASK INTERRUPTIONS AND PERFORMANCE IN HEALTH CARE

3.1 Introduction

This chapter discusses the effects of interruptions on performance and the nature of interruptions in health care. Hospital nurses routinely experience interruptions, which account for many medical errors (Pape, 2003; United States Pharmacopoeia, 2003). One study showed that nurses experienced more than 16 interruptions per hour in an intensive care unit (Alvarez & Coiera, 2005), and other studies found more than ten interruptions per hour in ICUs and emergency departments, which means that nurses can get interrupted about every six minutes (Biron, Loiselle, & Lavoie-Tremblay, 2009; Drews, 2007). Therefore, managing interruptions has a potentially significant impact on performance because studies have empirically shown that interruptions can increase medical errors (Flynn, et al., 1999; Westbrook, et al., 2010). In fact, given that the majority of interruptions originate from people, not phone calls or equipment alarms, and studies in architecture and management showed that the design of the environment can affect interruptions, a similar role of the physical environment in the interruption events might be found in health care.

3.2 Review Methods and Scope

The review in this chapter utilized research literature databases that include MEDLINE, CINAHL, Web of Science, PsycINFO, and Academic Search Complete, using keywords including but not limited to; interruption, distraction, medication error, nurse, and hospital. Similar to Chapter 2, the reference section of each article was reviewed for additional literature, and a reverse search was done to find articles that referenced articles that were found. The review focused on interruptions related to nurses, including studies that examined both overall activities and medication administration of inpatient units in hospitals and long-term care facility. The only study that examined an outpatient facility was done in a chemotherapy daycare unit (Trbovich, Prakash, Stewart, Trip, & Savage, 2010).

3.3 Results

3.3.1 Interruptions and Performance in Healthcare

The Institute of Medicine reported that based on a 1997 study, as many as 98,000 Americans die each year due to preventable medical errors, and medication-related errors increased hospital costs by $4,700 per admission or $2.8 million per year for the 700-bed hospital studied (Institute of Medicine, 2000). It is not clear how many interruptions might have contributed to these errors, but experts and clinicians have suggested that interruptions play a role in the number of errors. It is estimated that more than 50% of healthcare errors are unfinished actions that interruptions might have contributed to (Grundgeiger & Sanderson, 2009). In addition, nurses mentioned that interruptions are the main reason for medication errors (McGillis Hall, Pedersen, & Fairley, 2010). From a human factors perspective, excessive stimulation such as interruptions and distractions challenges an individual's limited cognitive capacity for attention. Interruptions can take away mental space for attention in an individual's working memory as mentioned in Chapter 1, and as a result, the individual might make an error because he or she cannot consistently focus and perform tasks accurately (Boehm-Davis & Remington, 2009; Pape, 2003). Although interruptions have a positive function, supporting communication in health care, their negative impact should not be ignored. Furthermore, their negative impact must be reduced during critical tasks (Grundgeiger, et al., 2008)

Westbrook and colleagues (2010) found that interruptions were significantly associated with procedural failures and clinical errors in their observation of 4,271 medication administrations. Interruptions occurred in 53.1% of administrations and each interruption increased clinical errors by 12.7%. In their study, 25.3% of administrations showed clinical errors without any interruptions but 38.9% with three interruptions. Interruptions and distractions sharply increased medication dispensing errors in a hospital pharmacy in which 14 pharmacists and 10 technicians were videotaped over 23 days (Flynn, et al., 1999). In a nursing home study with three to four days of observation at each of five sites, researchers found a significant relationship between the interruptions and the medication errors of nurses and medication aides (Scott-Cawiezell, et al., 2007). In the study, RNs experienced the highest rate of interruptions during medication administration (39.9%) and had the highest rate of errors (7.4%) when wrong time (delay) errors were excluded

A study with a patient simulator in anesthesiology showed that three anesthesiologists successfully “retrieved” the original task, the cross checking of blood, without external cues after they were interrupted by a surgeon; seven retrieved after an interruption only after a visual cue, the blood bag label; and two failed to retrieve out of total 12 anesthesiologists (Grundgeiger, et al., 2008; Liu, Grundgeiger, Sanderson, Jenkins, & Leane, 2009). Drews (2007) observed 1,138 activities of direct and indirect patient care, documentation, housekeeping, and administrative tasks by nurses for 34 hours and found that 29.4% of activities were interrupted. Among the interrupted activities, 12% were subsequently abandoned and 20% were delayed by 30 to 225 minutes before being resumed (Drews, 2007)

3.3.2 Nature of Interruptions

Understanding the sources and causes of interruptions will facilitate the development of strategies for managing them. For example, nurses get interrupted more often by other nurses than other types of healthcare workers, and their coordination role that connects different parts of the healthcare system might inherently lead to their being interrupted as often as ten times per hour as mentioned earlier. The contents of interruptions are often related to patient care, but some studies also suggest that most of them were personal matters.

3.3.2.1 Interruption Sources

In studies that observed either the overall activities of nurses or medication administration only, other people in the healthcare environment were the major source of interruptions to nurses (Biron, Loiselle, et al., 2009; Drews, 2007; McGillis Hall, et al., 2010; Scott-Cawiezell, et al., 2007; Trbovich, et al., 2010). From 480 hours of observations of nurse activities in six surgical and medical units of three hospitals, a study recorded 1,687 interruptions (McGillis Hall, et al., 2010). Almost a third (31.8 percent) of the interruptions was by other staff such as physicians, therapists, and others, and almost a quarter (22.4 percent) was by other nurses. Nurses in medical units experienced more interruptions by other staff than those in surgical units. Although nurses were more likely to be interrupted by patients and families, and visitors in surgical units than in medical units, the difference was not statistically significant. Nurses in surgical units were also more likely to interrupt themselves than those in medical units.

For example, they self-interrupted when they did not have all needed supplies for a procedure (McGillis Hall, et al., 2010). Another study that observed a medical intensive care unit also found that the majority of interruptions came from other staff such as other nurses (37.3 percent of 335 interruptions) and physicians (14 percent) (Drews, 2007). A study in an emergency department also found that other healthcare workers were the most frequent source of interruptions (Brixey, et al., 2008)

Not surprisingly, most interruptions during medication administration also came from others, not phone calls or alarms. One study that observed 374 interruptions over 59 hours and 2 minutes during medication administration found that 31.8 percent of interruptions came from other staff members such as physicians, orderlies, and other professionals, excluding nurses. Nurses accounted for 17.8 percent and patients and families 16.2 percent of the interruptions (Biron, Lavoie-Tremblay, et al., 2009). Kreckler (2008) found that other nurses accounted for 17 percent of interruptions during 38 medication administration rounds in an acute surgical unit. Physicians accounted for about 21 percent, self-initiated interruptions 21 percent, and patients and families 14 percent (Kreckler, et al., 2008). Other studies that observed interruptions during medication administration also found people to be the major source of interruptions (Elganzouri, Standish, & Androwich, 2009; Pape, 2003; Trbovich, et al., 2010).

3.3.2.2 Causes Inherent to the Healthcare Work Environment

The complexity of health care stems from the ever-changing conditions of patients, and nurses often have to change a plan for patient care with new information in the middle of an ongoing process (Tucker & Spear, 2006). As nurses receive updates from doctors and others, they need to make adjustments to treatment plans because patient conditions change and healthcare workers prefer face-to-face interactions for communicating the adjustments (Becker, 2007; Biron, Lavoie-Tremblay, et al., 2009; Coiera & Tombs, 1998). Clinicians care about patients and want to resolve care management issues quickly so that they can be relieved from pending care issues that are a mental burden. Therefore, they often prefer to talk face-to-face and often interrupt each other so that they can quickly resolve the issues (Alvarez & Coiera, 2005), even if it is neither effective nor efficient (Parker & Coiera, 2000). One nurse commented that a physician would interrupt the task at hand and inform her that he had just ordered a new drug for a patient, which might be an illustration of good communication; however, the nurse felt frustrated and interrupted because she knew how to find new orders from the chart and would have checked the order when the task at hand was complete (Tucker & Spear, 2006).

Healthcare workers frequently get interrupted even during critical tasks such as medication administration and procedures in surgery and the emergency department (Biron, Loiselle, et al., 2009; Chisholm, Collison, Nelson, & Cordell, 2000; Grundgeiger & Sanderson, 2009; Sevdalis, Forrest, Undre, Darzi, & Vincent, 2008). The health care work environment might have a particularly interrupt-driven culture that reflects its complicated and fragmented system of services and procedures. Workflow in the healthcare system is often disrupted by missing or delayed information, services, and supplies (Tucker & Spear, 2006). At the center of the system, nurses play a significant coordination role between its fragmented parts. They have to make sure that patients receive the correct services they are supposed to get, which may include lab tests, imaging, medication changes, physical therapy, and others. Nurses spend more time on coordination (34-49 percent) than on direct care (31-44 percent). As a result, they have to constantly interact with other functions of the healthcare system to update information regarding patient care, so they are prone to interruptions (Tucker & Spear, 2006).

Another example of fragmented functions of the healthcare system that might increase interruptions is the mismatch or lack of coordination in the timing of procedures from different service providers who arrive at a patient unit at different times. Nurses might be administering medications or be at the bedside performing a procedure when various providers enter the patient room, interrupting the nurses' tasks. In addition, family members and visitors might be asking questions or making requests while nurses are working on patients. Studies show that interruptions from providers, patients, and family members occur regardless of the tasks nurses are working on (McGillis Hall, et al., 2010).

3.3.2.3 Contents of Interruptions as Causes

Interruptions are a form of communication, so identifying the content of interruptions will help clarify the causes of interruptions and develop strategies to mitigate them. One study showed that other nurses contributed the most interruptions during medication preparation and found that the most frequent content of interruptions was a personal matter (Biron, Lavoie-Tremblay, et al., 2009). Other studies also found substantial interruptions of a personal nature during medication administration (Seo, Choi, & Zimring, 2011; Trbovich, et al., 2010). Although personal conversations might benefit social relationships and teamwork (Becker, 2007) they should be managed so that they do not increase the cognitive load of nurses while they are performing critical tasks such as medication administration (DeLucia, Ott, & Palmieri, 2009; Grundgeiger, et al., 2008).

However, other studies have not found personal conversation to be the main cause of interruptions. From a time-motion study of 151 medication administrations in medical-surgical units, Elganzouri and colleagues (2009) found that patient care issues were the most frequent content of interruptions. Biron and colleagues (2009) found that personal conversations comprise only 7.5 percent of interruptions during medication administration while direct care (30.1 percent), coordination (19.9), and failure solution (18.5) comprised the majority of the 374 interruptions observed, even when nurses were the most frequent (17.8 percent followed by self-initiated, 16.9 percent) source of the interruptions in a medical care unit. A study in a chemotherapy unit where 17 nurses were observed for three hours each during medication administration found that asking questions and pump alarm-related conversations contributed to 39.6 percent and 27.3 percent of interruptions, respectively, while personal conversations contributed to 16.2 percent, as shown in Table 3.1.

3.4 Discussion and Conclusion

Healthcare workers might accept interruptions as routine incidents in their work because they need to interact with a system that is not always predictable. For example, information, services, and materials might not be available when they are needed, so when they are available, healthcare workers may want them immediately even if they conflict with their own tasks. Regardless of the tasks they are performing, healthcare workers often get interrupted, and if they are more visible and accessible, they may be interrupted even more often. Thus, because the built environment can determine how visible and accessible individuals are in areas with boundaries such as walls, its role can become significant to the management of interruptions.

3.4.1 Culture of Interruption in Health Care

The fact that nurses get frequently interrupted has been well acknowledged in the healthcare research literature. The work environment of nurses might be described as "interruption-driven." After all, healthcare workers might not use their discretion when they interrupt others because they do not want to delay the care of their patients, and when interrupted, they probably understand that others feel the same way. In the complicated and fragmented healthcare system where information, service, and materials are seldom available in a timely manner, healthcare workers have to accept interruptions and deal with them when services become available, which may not coordinate with their own tasks in a timely manner (Tucker & Spear, 2006).

Therefore, they might consider interruptions as routine events even during their tasks, which might be reflected in the substantial number of interruptions initiated by nurses themselves even during critical tasks such as medication administration. In one study in which nurses were observed for 480 hours, five percent of the time was spent on self-initiated interruptions during medication administration (McGillis Hall, et al., 2010). Other studies found an even higher percentage of time spent on self-initiated interruptions during medication administration. Kreckler and colleagues (2008) found that out of total 99 interruptions during 38 medication administration rounds, 21 were self-initiated. In another study, almost 17 percent of 366 interruptions during medication administration were self-initiated (Biron, Lavoie-Tremblay, et al., 2009).

In the study by McGillis Hall and colleagues (2010), 19 percent of interruptions out of total of 1,687 interruptions of overall activities occurred during medication administration. Considering that other studies found a similar percentage of 17 percent of the time spent on medication administration among the overall activities of nurses (Hendrich, et al., 2009), the similar or slightly higher percentage of interruptions (19%) during medication administration out of all the interruptions might also indicate that healthcare workers might not be mindful of what tasks nurses are working on. As mentioned earlier, nurses were interrupted regardless of their tasks at hand (McGillis Hall, et al., 2010).

3.4.2 The Role of the Physical Environment

As healthcare workers do not mind interrupting nurses or others regardless of the tasks being performed, this behavior might be more likely to change where the physical environment supports such a change. In physical environments in which healthcare workers are visible and accessible (Bafna, 2003), others are more likely to interrupt them regardless of the task they are performing. Therefore, if designs do not appropriately include barriers, for example, partitions or walls for medication area, the number of interruptions might increase. For example, one study found that a significant number (20 percent of 43 interruptions over 10 hour period) of interruptions occurred in a medication room that was visible from a high level of staff movement (Potter, et al., 2005). Other studies have shown evidence that nurses in a medication room are likely to talk to each other because of their proximity and less likely to get interrupted if medication cabinets are located in patient rooms instead (Biron, Lavoie-Tremblay, et al., 2009). However, if medication administration is done closer to patient rooms, patients and family members can also be a source of interruptions. Therefore, medication administration should be supported by a system and a physical environment that provides a sustainable reduction of interruptions (Biron, Lavoie-Tremblay, et al., 2009).

In addition, given that studies of office settings have shown that visibility and accessibility, determined by the physical environment, are associated with a higher number of interruptions and distractions as described in Chapter 2, the physical environment of hospitals might also affect the number of interruptions of healthcare workers. However, few studies have examined the role of the physical environment in interruptions in architecture, especially in healthcare settings. In Chapter 2, I examined different views on chance encounters depending on social and culture environments. For critical tasks in health care such as medication administration, a reduction of interruptions is crucial for optimal task performance. However, for other less critical tasks, views such as the socio-relational view mentioned in Chapter 2 should also be considered in the design of the physical environment to support opportunities for communication and the development of social relationships in the healthcare environment.

Studies have examined or mentioned strategies for reducing interruptions during, for example, medication administration, which might be incorporated into physical environment strategies. One study in which the floor around medication administration areas was designated with red duct tape to create no-interruption zones found that that the rate of interruptions dropped from 31.8 percent to 18.8 percent during eight hours of observation each both before and after implementation (Anthony, Wiencek, Bauer, Daly, & Anthony, 2010). Another study found that wearing a red vest with the statement "Medsafe Nurse, Do Not Disturb " decreased the number of distractions from 484 to 64 (Pape, 2003). However, whether the effectiveness of the no-interruption-zone or wearing a vest would last for long after these studies ended has not been verified.

Operational strategies that reduce interruptions might include the following: Healthcare workers could review patient information on charts regularly so that they would not interrupt nurses during patient care (McGillis Hall, et al., 2010), and hospitals might establish "do not disturb" times, provide phone and call-bell support for nurses administering medications, and educate staff and patients and family members about the interruption issue (Smetzer & Cohen, 2006). Combined with the physical environment strategies, these strategies might build a lasting culture in which significantly fewer interruptions occur while nurses are performing critical tasks.

Table 3.1: Summary of Studies on Interruptions in Health Care: Characteristics of Interruptions

STUDY	SETTING	SAMPLE	TOTAL NO. AND INT. /HR	SOURCE OF INTERRUPTIONS (%)										CONTENT OF INTERRUPTIONS (%)				
				Self	nurse	doc	others	Orderly/clerk	patients	relative of patients	system failure	phone and pager	alarms	Direct care	communication	Coordination	Failure resolution	Personal
Biron(2009) Characteristics of Work Interruptions During Medication Administration	a medical care unit at a teaching hospital	102 **medication administration** event sampling	total 366 interrup--tions; 6.3/hr	16.9	17.8	5.5	15.3	4.4	10.7	5.5	14.8	na	2.7	30.1	5	19.9	18.5	7.5
Brixey (2008) Interruptions in a level one trauma center	ED in a major urban medical center	5 attending docs observed for 29h 31m, 8 RNs were shadowed for 40h 9min	11+/hr	10	65						na	20	na	na	na	na	na	na
Drews, F. (2007) The frequency and impact of task interruptions in the ICU	medical ICU	9 of 3-4 hr observation, 335 activities (29.4%) were interrupted out of total 1138 activities	10/hr	na	37.3	14	na	na	8.7	2.1	na	7.1	19	na	na	na	na	na
Hedberg (2004) Environmental elements affecting the decision-making process in nursing practice	medical unit, geriatric rehabilitation unit, primary health care unit	2 nurses from each type of setting, total 6 nurses observed for 30 hours in total	2.8/hr total 85 interrup--tions	na	36.5	9.5	na	8	25	8	na	13		exchange of information, instructions, and assistance				

Table 3.2: Summary of Studies on Interruptions in Health Care: Characteristics of Interruptions (*Continued)*

STUDY	SETTING	SAMPLE	TOTAL NO. AND INT. /HR	SOURCE OF INTERRUPTIONS (%)										CONTENT OF INTERRUPTIONS (%)				
				Self	nurse	doc	others	Orderly/clerk	patients	relative of patients	system failure	phone and pager	alarms	Direct care	communication	Coordination	Failure resolution	Personal
Kreckler(2008) Interruptions during drug rounds: an observational study	Acute surgical unit	38 **medication administra-tion rounds**	total 99; 11% spent on interrupt-tions	21	17	21	na	na	11	3	na	8	na	23	info seek 19	10	equip seek 20	na
McGillis Hall (2010) Losing the moment: understanding interruptions to nurses' work	6 medical and surgical units of 3 hospitals	480 hours of observation for all activities	total 1687 interrup-tions	5	22.4	31.8			20.1		1.7	na	na	patient 16.3	57.3	na	waiting or finding 22	environment noise 4.4
Pape, T. M. (2003) Applying airline safety practices to medication administration.	Medical-surgical unit acute care of hospital in a metropolitan city	8 **medication** cycle	no time measure	na	19.38 times per medication cycle	1.75 times	na	na	na	1.75 times	missing and wrong dose med 2.76	8.38 times	na	na	na	na	na	na
Trbovich(2010) Interruptions during the delivery of high-risk medications	Chemo-therapy daycare unit	Nurse **medication administra-tion** (17 nurses for 3 hours each)	no mention	na	35.2	na	na	na	29.6	7.4	na	na	20	na	Question: 39.6		pump alarm: 27.3	16.2

CHAPTER 4

RESEARCH OUTLINE

4.1 Introduction

In this chapter, I describe a research design that investigates how the physical environment such as a hospital unit layout contributes to interruptions. For the investigation, a healthcare setting was chosen, in part because the effects of the physical environment on interruptions have rarely been examined despite their impact on medical errors. Also chosen was the nursing task of medication administration because it is relatively standardized across hospitals, plus the beginning and end are identifiable by observation. Choosing a specific task such as medication administration allows the study to control for the effects of various tasks in hospitals. Observing other various activities might make it difficult to identify the effect of the physical environment on nurses' behavior, which can be affected by different tasks significantly. Observing the same task, medication administration by nurses, within the same specialty across three differently designed wings of the same healthcare units provided an excellent opportunity to identify the effects of the physical layout of the units. In addition, medication administration is one of the critical tasks that can be a major source of medical errors (Smetzer & Cohen, 2006).

4.2 Assumptions

Based on the review of research literature in previous chapters, in this chapter, I make assumptions about the perspectives on interruptions that occur during medication administration and nurses' acceptance of interruptions or interactions. As mentioned earlier, studies have shown that interruptions contribute to medical errors which can be fatal to individuals and costly to healthcare systems (Institute of Medicine, 2000; Westbrook, et al., 2010). I will therefore assume that interruptions that occur during medication administration are undesirable events and that interruptions during medication administration are not justified unless there is an emergency. Medication administration itself is a critical task and the socio-technical perspective can be applied to interruptions rather than the socio relational perspective that was mentioned in Chapter 2 as shown in Table 4.1.

Table 4.1: Task Types and Impact of Interruptions

	Nurses' Ongoing Tasks								
Activity	Emergency	Meds Adm.	Bed-side Procedure	Communication with family	Documentation	Communication with staff	Look for equipment or person	Wait	Copy/Fax
Location	Patient Room	Patient Room/ Meds Room/Hallway	Patient Room	Patient room	Nurse Station	Sub/Nurse Station	Everywhere	Nurse Station/Patient room	Nurse Station

However, culture of healthcare workers does not seem to reflect this social designation for undesired interruptions during the critical task. Given the coordination role that nurses have to play, they often get interrupted regardless of their tasks at hand. They have to constantly check the status of patient information, and this information changes and comes from multiple sources that are unpredictable, therefore, they need to communicate instantaneously and prefer person-to-person communications as mentioned in Chapter 3. They do not want to delay patient care when service or material is available, so they interrupt others and allow interruptions to them for the care, and they understand others do the same. The nature and culture of the nurses' work environment might make them accept interruptions. Therefore, I assume that nurses interrupt others and get interrupted as routine with little discretion, which makes interruptions unpredictable. This implies that interruption events are more affected by the physical environment than by individual or task differences because the physical environment can determine who nurses and other healthcare workers see and access.

Although, methodologically, I focus solely on medication administration in order to control task types, interruption is a common social phenomenon that can potentially affect any activity in a space. Patterns of interruption for medication administration may be representative of interruptions of a broader range of activities as it is a well known high-priority activity that is not supposed to be interrupted.

4.3 Hypotheses

Architectural and organizational studies have shown that visibility and accessibility, which are determined by design of office environments, can affect interruptions and interactions, as described in Chapter 2. I propose that similar effects of the physical environment will be identified in healthcare settings as well (Westbrook, et al., 2010). People are more likely to interact in an area where they can see each other better and the movement of others is more present with high accessibility (Bafna, 2003; Oldham, et al., 1995; Penn & Desyllas, 1999; Rashid, et al., 2006). Accessibility here is measured as the number of turns needed to reach one area from other areas (Bafna, 2003). In addition, if people are exposed to others longer, for example if they need to walk longer distance, they might have more chance of interacting with others. Based on controlled observations of a single task, medication administration, I therefore propose the following hypotheses:

1. Nurses will be interrupted more frequently when they are in areas where they can see others and are seen more easily by others
2. Nurses will be interrupted more when they are in areas that are more accessible (reachable with fewer turns) by others
3. Nurse will be interrupted more when they need to walk farther to do their tasks, because they get exposed to other people for longer periods of time.

4.4 Methods

4.4.1 Settings

I chose two neurological ICUs at a university hospital in Atlanta, Georgia. The units were chosen because they had the same service line, neurology, and the same nurse pool across three differently designed wings of 2D and 2G ICUs as shown in Figure 4.1. Each nurse is typically assigned two patients except one nurse in 2G ICU where one nurse gets assigned to only one patient because the unit has seven patient rooms. Patients are randomly assigned to these units wherever a room is available, and rooms are typically full.

However, these units are considerably different in terms of physical design. 2G is an older unit that has an open floor plan with a traditional ICU layout where a nurse can watch all the patients from the central nurse station, while a nurse in 2D ICU cannot see all patients from the central nurse station and the unit has distributed substations to accommodate a larger number of patients. The west wing of 2D ICU has sixteen patient rooms while the east wing has six, and

2G has seven. The layout difference in these units will provide variations in terms of visibility, accessibility, and distance to each patient assignment of nurses. All three wings in 2D and 2G ICUs have only one medication station and nurse station each. For the analysis of variables, patient rooms and other rooms such as supply rooms that had typically closed doors were not included in the analysis because these areas were not likely to be the source of interruptions.

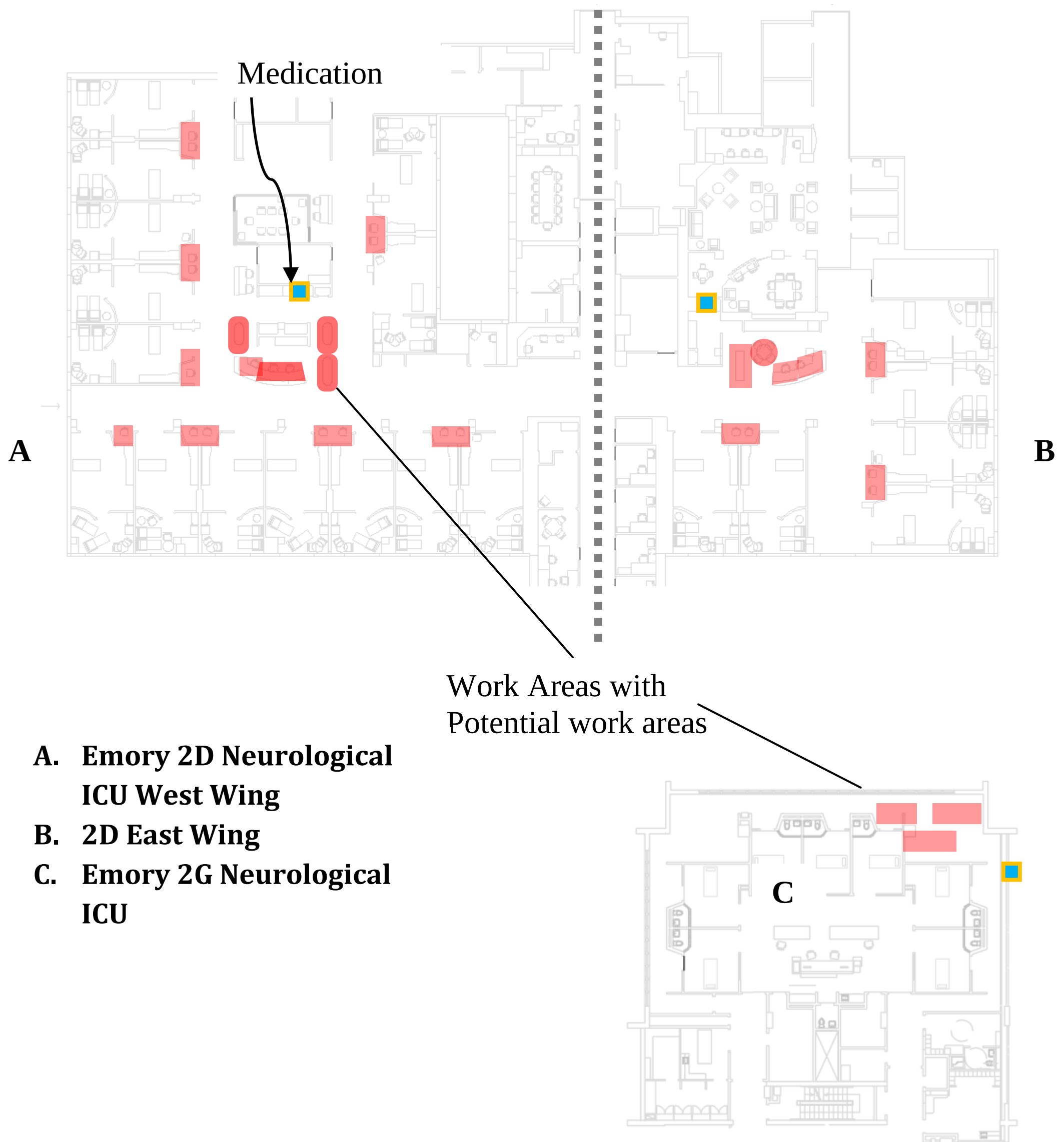


Figure 4.1: Study Settings: Three Wings and Potential Work Areas

4.4.2 Observation of Medication Administration

In this thesis, I observed nurses' medication retrieval during their daytime shifts from 8:30am to 6:00pm. All nurses had at least one year of experience, which was judged by nurses in the unit to be sufficient for independent work according to nurses in the unit. The medication administration task is relatively standardized process across units and hospitals and is one of the critical tasks that can involve serious errors. The task is also visually identifiable by non-clinicians in part because nurses use a distinctive medication distribution machine and the beginning and end of the task are relatively obvious. The task involves a walking trip by the nurses through the unit layout, and shadowing nurses' trips provides information on their spatial experience when they are involved in interruptions. The spatial experience around interruptions might explain how interruptions happened because the cue for interruptions might have already happened before actual interruption happens, and this information might not be available if I observed only the location of interruptions. However, simply recording the paths of nurses on floor plans might not be always very accurate because they are moving relatively quickly in space.

Observation started as a nurse approached the medication distribution machine, actual recording started when they arrived at the machine, and it ended when they entered a patient room for medication administration. I used floor plans and coding (Table 4.2) for observation recording that included nurses' walking paths, the number and location of interruptions, the content of each interruption (work-related or private), the initiation of each interruption(self or others), and the role of the person involved in the interruption (nurse, physician, clerk, patient, family, or other staff). The duration of interruptions was recorded in 5 second increments rounding up to the nearest 5 second interval. For example, if a nurse was interrupted by a physician for about 9 seconds and it was a private conversation that was initiated by the physician, the coding will be “id2=10s” (Table 4.2). In the data analysis, the number of interruptions was tested to see if it can be predicted by independent variables: visibility, accessibility, and distance of the medication trip path.

Table 4.2: Coding for Interruption Observation Recording

Recording		Coding
Interruption		i
Personnel	Nurse	n
	Charge nurse	cn
	Nurse Practitioner	np
	Doctor	d
	Patient	pt
	Family	f
	Staff	s
Content	Work-related	1
	Private	2
	Switch Tasks	st
Duration	Seconds	s
	Minutes	m
Initiator		__ (underline)

4.5 Variables

All variables in the hypotheses (visibility, accessibility, distance, and interruption) were measured for a specific task: medication administration. The measurements were done along the path of medication trips from a medication station to a patient room. To recap, each hypothesis is shown with relevant variables that are explained in the following sections:

1. Nurses will be interrupted more frequently when they are in areas where they can see others and are seen more easily by others; visibility and interruptions.
2. Nurses will be interrupted more when they are in areas that are more accessible (reachable with fewer turns) by others; accessibility (integration) and interruptions.
3. Nurse will be interrupted more when they need to walk farther to do their tasks, because they get exposed to other people for longer periods of time; distance and interruptions.

4.5.1 Visibility

4.5.1.1 Definition

I defined the visibility value as average visibility to potential work areas from nurses' paths for medication trips. The potential work areas were areas with horizontal work surfaces (such as desks and countertops) and the peripheries of these areas, which were extended by 2 feet to include space for sitting and standing. Other staff are more likely to be present in these areas because they have work surfaces (as well as seating) available, and these facts were noticed during the field observation. Although it has not yet been verified by systematic observation, observing areas with work surfaces (and their peripheries) might be useful in identifying the areas as sources of interruptions in other settings as well. Potential work areas around horizontal work surfaces can be easily identified in a similar way in other settings as potential sources of interruptions.

4.5.1.2 Process

The average visibility of work areas was calculated by a computer program called Depthmap (Turner, 2010). This program uses an architectural representation of a floor plan in the AutoCad format as an input and overlays small square tiles (for example, one foot by one foot) on the floor plan. The program counts all the tiles that it can reach from any particular tile with straight lines without going through boundaries such as walls. These counts are calculated as visibility (John Peponis, et al., 2007). An actual graph of visibility analysis for the 2D West wing is shown in Figure 4.2, where color ranges from red to blue represent values from high to low. For this thesis, I calculated how many tiles in potential work areas can be reached from tiles of the task path by a straight line (Lu, Peponis, & Zimring, 2009). On the visibility analysis graph, I overlaid path drawings and then I traced the path by selecting tiles. The average visibility is automatically calculated for selected tiles by the program (Figure 4.2).

4.5.2 Accessibility

4.5.2.1 Definition

The accessibility of a space is measured by its integration value, a method that has been frequently used in architecture in the field of space syntax (Bafna, 2003; John Peponis, et al., 2007). Integration measures the average number of physical turns or changes in direction needed to travel from a space such as a room to all other spaces on a floor plan. How the integration value is measured can be explained by axial lines that are drawn on a floor plan as straight lines that extend out to every other space. These lines are drawn using the fewest and longest straight lines possible, which connect all spaces as shown in Figure 4.3. The integration value is higher if a line is intersected by more lines, and in that case those lines are shown thicker. Therefore, high integration value means that someone has more options for accessing other spaces from the space from which the axial line is drawn. In other words, accessibility is measured by the number of turns needed from an axial line or a space to another, and integration value is calculated as the average number of turns needed to reach all axial lines or spaces.

4.5.2.2 Process

Integration value also can be calculated by Depthmap program using floor plans as an input. The nurses' path was overlaid on the integration graph and tiles were selected to trace the path. An actual graph for integration for the 2D West wing is shown in Figure 4.4 as an example and color values ranges from red to blue representing higher to lower value. Both the visibility and integration values are measured for hallways and other common areas such as nurse stations and medication areas that nurses might access during medication trips, but not for patient rooms because staff and patients in patient rooms are not likely to be accessible to nurses who are walking in a hallway for medication (this happened only once among all 83 observations).

4.5.3 Distance

4.5.3.1 Definition

Walking distance along the path was measured as distance, which was linear distance between start and end points of walking from a medication station to a patient room door by nurses for medication trips.

4.5.3.2 Process

The distance of a path was measured by the number of tiles selected along the path in the Depthmap program (Figure 4.2) that displays the number automatically.

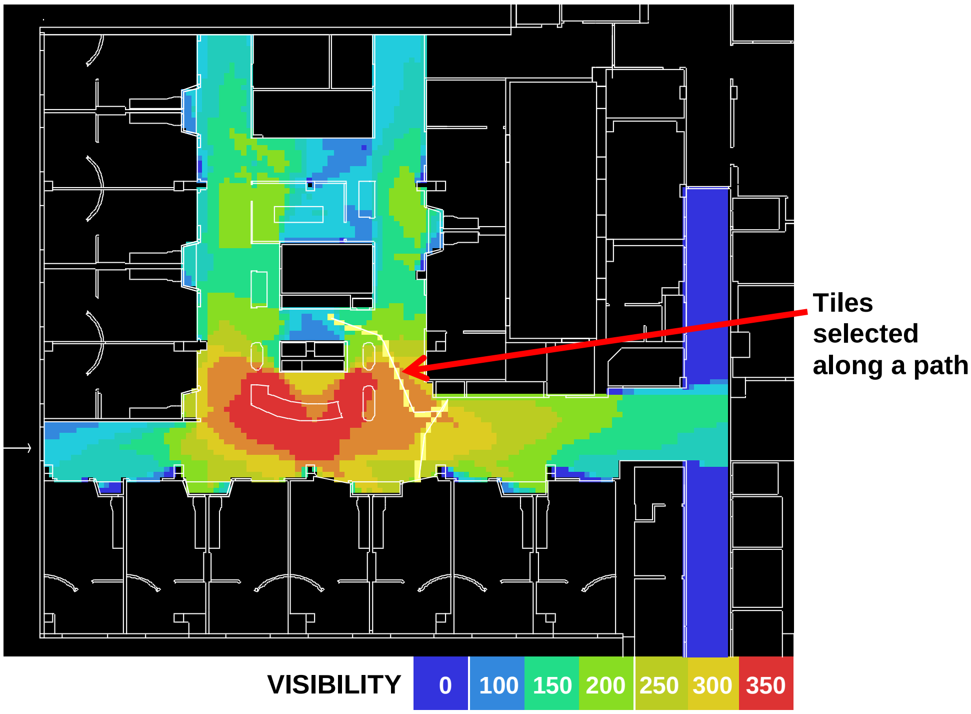


Figure 4.2: Analysis of Visibility to Work Areas by Depthmap Program: Measurement for Path (2D West)

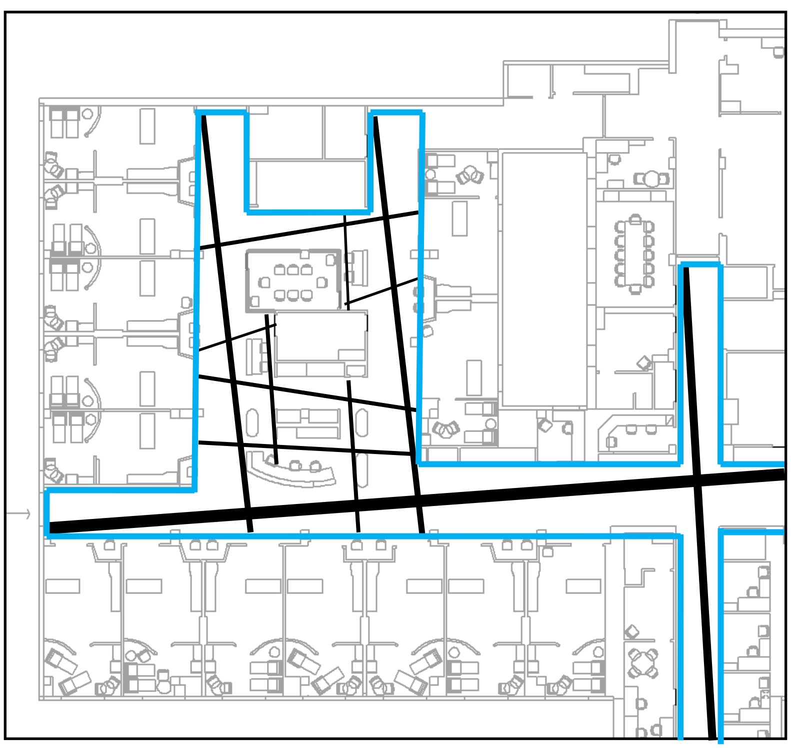


Figure 4.3: Axial Lines for Accessibility (2D West)

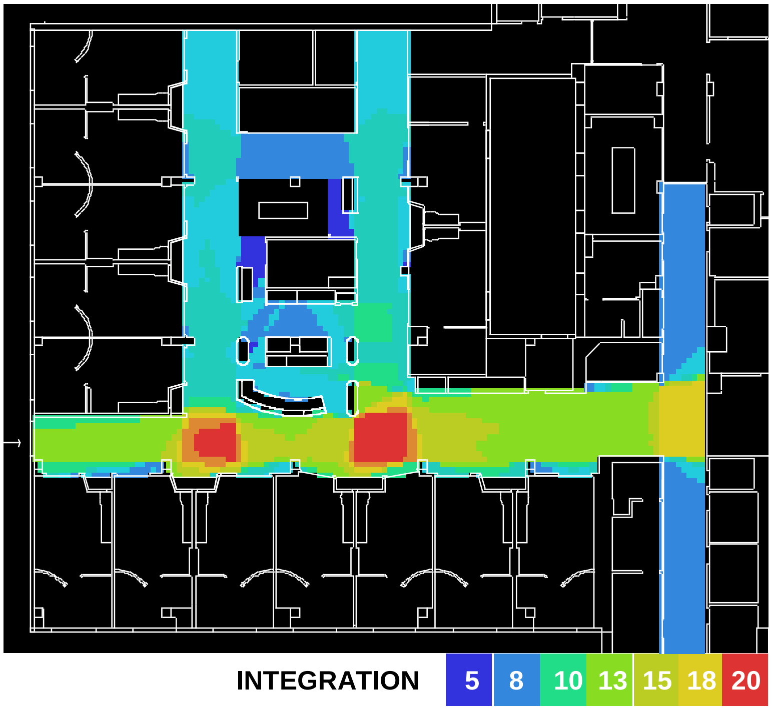


Figure 4.4: Analysis of Integration (Accessibility) by Depthmap Program (2D West)

4.5.4 Interruptions

<u>4.5.4.1 Definition</u>

An interruption was any verbal interaction between the nurse who was getting medication and other people. Non-verbal interruptions such as making extra trips to the same location or responding to alarms were not included. For testing the effects of independent variables, the dependent variable was narrowed down to the number of interruptions that were initiated by others during medication trips not including ones around medication station. The medication trip was from a medication distribution machine to a patient room door. Only interruptions by others were counted in examining the effects of the physical environment, because self-initiated interruptions might have been planned by nurses in advance. Interruptions around medication station areas were not included because nurses tend to stay there for a certain amount of time to get medication out and get interrupted simply because they spend so much time there, not because of the design of the unit layout. In addition, some nurses will be around medication stations to get medications and interruptions from them happen not because of unit layout design but because they came to get medications. Nurses also might feel obligated to talk with other nurses around medication stations especially when the station is in a small room or is partially or fully enclosed by partitions, obligating social interaction in a way that is similar to people in a photocopier room of relatively small size as mentioned in Chapter 2 (Fayard & Weeks, 2007).

4.5.4.2 Process

Interruption recording on floor plans started upon nurses' arrival at a medication station and all interruptions were recorded until nurses went into patient rooms using coding in Table 4.2. Interruptions recorded included both self-initiated and ones initiated by others and also those occurring around medication stations. Multiple floor plans were used as needed. Location of the nurse at the time of interruption was marked by a short line that was perpendicular to the path lines. If possible, location of the person who was involved in the interruptions was marked with coding that showed the role of the person and a circle that encompasses two locations was drawn (Figure 4.5). For the analysis, interruptions were selected as needed such as ones initiated by others and excluding ones around medication stations.

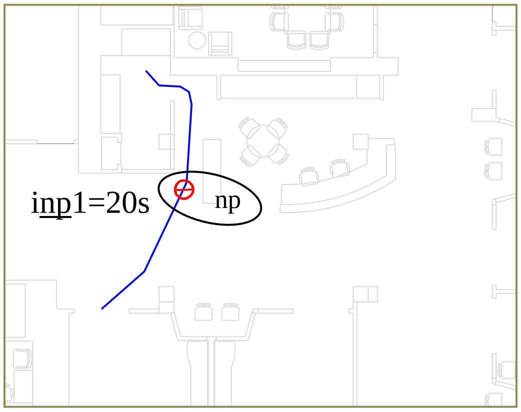


Figure 4.5 Floor Plan Observation Recording Example

4.6 Unit of Analysis

In this thesis, nurses were observed while they walked from a medication station to a patient room. Nurses are exposed to their work environment along their walking path when they get medications, and nurses' behavior might be examined by the whole path of the trip because it might be how they perceive the environment. They might say that the medication room is far away or how others see them as they describe their spatial exposure while on the path as a whole. However, if we take the entire path as shown in "A" in Figure 4.6, we might not identify different characteristics of different parts of the path because not every part has effects on interruptions. For example, the nurse's path in Figure 4.6 goes through a nurse station as it starts from a medication station where a nurse might be visible and accessible to others, but as the nurse gets closer to patient room "A", the nurse might not be as visible and accessible particularly after crossing the line "C" (the nurse cannot see substation "B" either after crossing the line toward the patient room). Therefore, measuring average visibility on, for example, the entire path might cancel out effects by putting both lower and higher values from each part of the path together. To resolve this issue, I used a method called “i-Partition” to define areas by their different levels of visibility.

4.6.1 i-Partition

“i-Partition” is used to mark where the transition happens from one area with a certain visibility level to another area with a different visibility level. When these areas that are defined by “i-Partition,” a path can be divided into segments. The idea of “i-Partition” originated from the works of Peponis and his colleagues (1997) on s- and e-partition. Partition lines are drawn to create space in a shape that has convexity in a 2-dimensional floor plan view. A convex space is where, from any point in the space, a line can be drawn to any other points in the same space without crossing the boundary (Figure 4.6). Therefore, studies have argued that the convex space reflects a space where every point is completely available for our intuitive experience and the space can be a discrete spatial unit that reflects our experience (Peponis, et al., 1997).

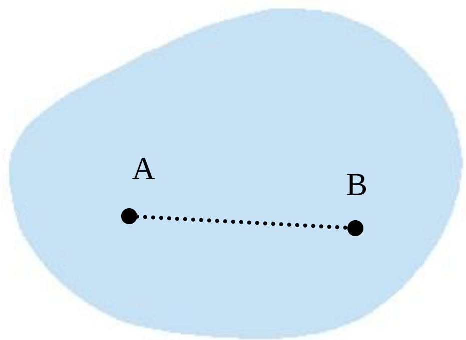
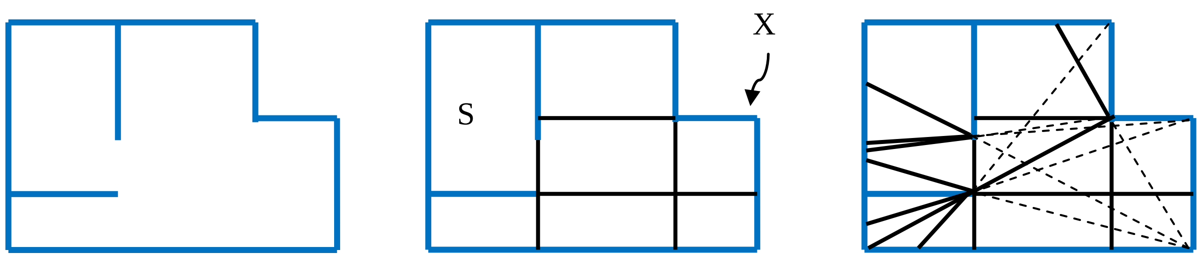


Figure 4.6 Convex Space

One method of creating this convex space on a floor plan is through partitioning called "s-Partition" which is drawn to account for the way that a built shape or surface appears to a moving person. This is generated by extending both walls of every corner and walls that have freestanding ends toward the area of interest (Figure 4.7). If we cross a partition (a black line on floor plan B in Figure 4.7), we see or cannot see the surface of the wall that the partition line is drawn from.



A **B (s-Partition)** **C (s- and e-Partition)**

Figure 4.7 Hypothetical Floor Plan and Partitions

However, there are surfaces or corners that appear or disappear even within a convex space with s-partitions. For example, one can see or cannot see corner "X" from within the space "S" depending on where the person stands on floor plan "B" in Figure 4.7. Therefore, to define a space that has uniform spatial information of surfaces, additional diagonal partition lines are drawn from the end point of walls including corners to demarcate where different surfaces or their discontinuities are visible or not. These partitions are shown in solid lines on floor plan "C" in Figure 4.7 (dotted lines are not partitions but show where each partition is drawn from). This end-point partition is called "e-partition" and when we cross each of these lines we can see or cannot see an end point or discontinuity of surfaces, and within a space that is defined by e-partitions, the same number of surfaces is visible.

E- and s-partitions are drawn to account for visibility to wall surfaces and their end-points. The same idea is applied to visibility for something meaningful for the activity or behavior of people such as the nurse station for “i-partition” The i-partition and s- and e-partitions are similar in that they divide space according to visibility to a target of interest but are different in how they determine what the targets are: “i” here stands for “information”.[1] With these lines, we can divide a path into segments as it goes through or transitions to different areas that are defined by “i-Partition” lines according to visibility. This way, we will be able to identify different levels of values for different parts of a path.

Therefore, I used “i-Partition” lines to divide a path into segments. For example, the line “C” in Figure 4.8 is one of the partition lines. This line marks the point where someone is first able to see the substation work area “B” while walking toward the medication station or where one can no longer see substation “B” at all while walking toward the patient. Other partition lines that are shown as blue solid lines can be drawn for other work areas in a similar way (Figure 4.9). These lines show where the transition happens from one area of visual information to another area of different visual information. People can see the same number of work areas within a space that is defined by partition lines in Figure 4.9.

[1] The concept of “i-Partition” was further developed from ideas by Sonit Bafna of the Georgia Institute of Technology

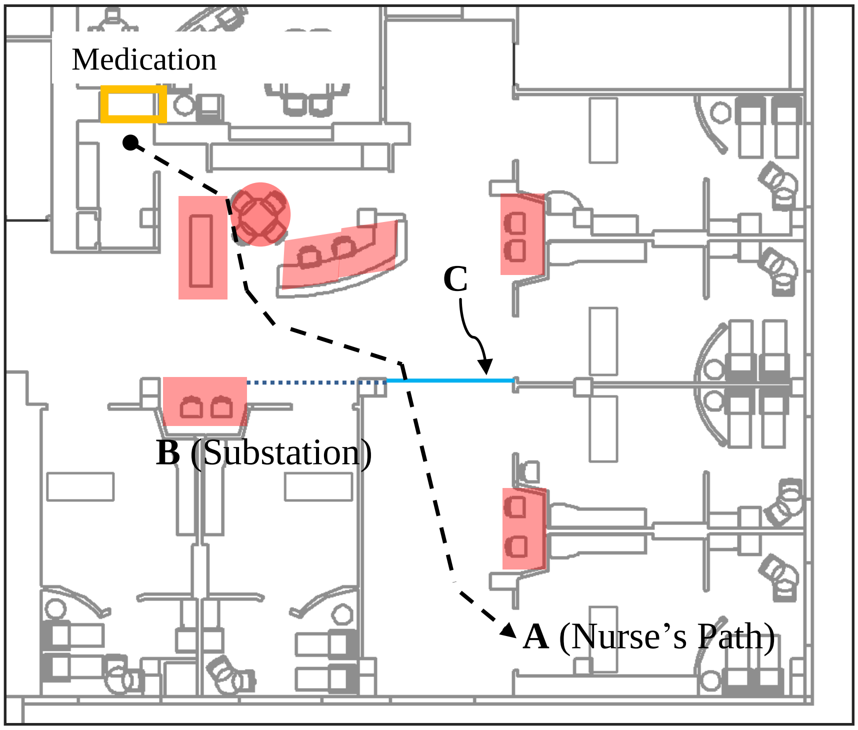


Figure 4.8: Entire Path for Measurement

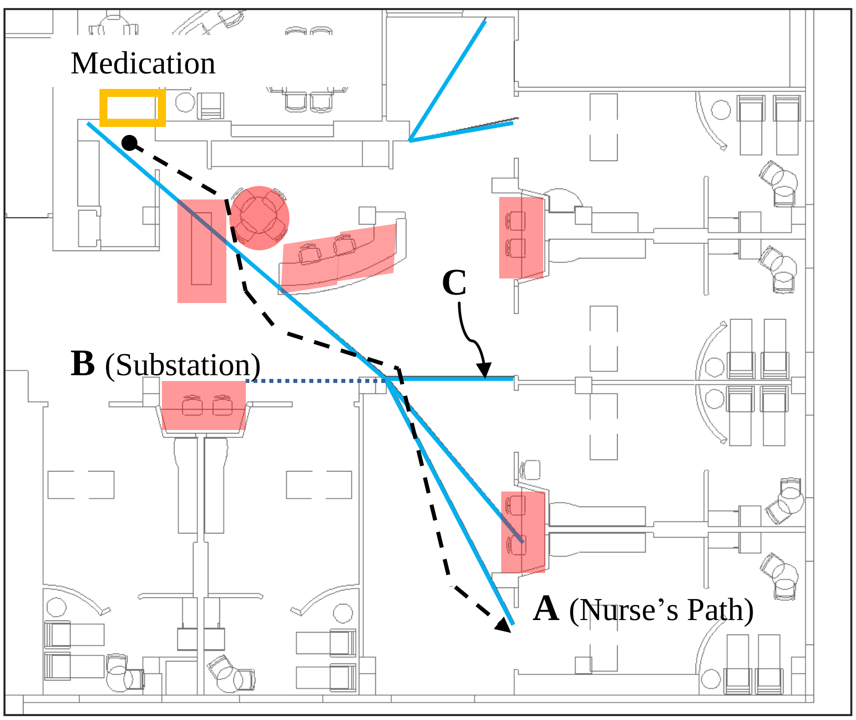


Figure 4.9: Path Segments by i-Partition: Reflecting Different Visibility by Segments

4.6.2 i-Partition Drawing Process

Drawing steps for "i-Partition" are the following:

1. Identify areas for the source of interruptions such as nurse stations and substations and define boundary corner points
2. Draw a diagonal line from a corner point of the interruption source areas to each discontinuous point of wall-lines (i.e., corners) without crossing a wall.
3. Some diagonals cannot be extended without going outside the shape while others can be extended from one or both ends within shape until it reaches a wall
4. Select extended lines but do not include diagonals itself for the "I"-partition
    a. If multiple i-partition lines can be drawn to one nurse station that has multiple points of boundaries, only draw the line for the first i-partition line that marks the nurse station as visible
    b. Likewise, for a series of substations on a wall, draw only first i-partition line that marks where a substation is beginning to be visible. If a substation is visible in the beginning, you might not draw the partition line at all.
5. Draw surface partitions where crossing the partition line gives a new source of information, for example, when one can see substations as one crosses a partition line.
6. If a path segment is less than 6 feet (the width of patient room door), the i-partition line that is generated from a substation or nurse station further away will be eliminated for the specific path.
7. Each path might use a different partition line depending on direction and the point where different parts of substation or nurse station are first visible

One interesting aspect of the partition line is that when we cross the line, the interruption source areas appear or disappear from our vision (Peponis, et al., 1997). The partition lines created path segments from which the independent and dependent variables were acquired.

4.7 Data Analysis

Observation results showed a skewed distribution with a zero interruption count as the highest frequency of interruptions, as shown in Figure 4.6. Given that the dependent variable is a count variable of interruptions, and that the count is a small number for each segment of the medication trip path, I used Poisson regression analysis was done with IBM SPSS statistical computer program version 19.

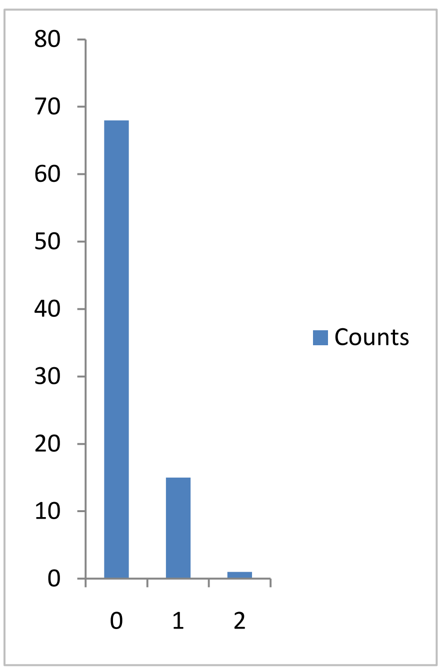


Figure 4.10: Low Counts for the Number of Interruptions per Trip: Poisson Distribution

Based on the hypothesis, a Poisson equation can be as follows:

> Log (number of interruptions by others) = B1*(average visibility from a path segment to work areas with surface) + B2*(average integration of a path segment) + B3*(segment length) + B.

All independent variables (overall visibility, visibility of the heads of patients, and distance between medication and assigned patient rooms) are measured along the path segments of the medication trips, which were divided by i-Partition lines from the entire path for each trip.

CHAPTER 5

RESULTS

5.1 Introduction

In this chapter, I describe characteristics of interruptions and analysis of observation data with Poisson regression analysis. Overall, 83 medication administrations were observed for 32 nurses. Among 69 interruptions observed in total, 37 were excluded from data analysis because they happened around medication stations where the medication process might have more effects than unit layout or the physical environment. As a result, 32 interruptions were used for describing the characteristics of interruptions in this chapter, and 14 interruptions initiated by others out of 32 were used for testing independent variables with the regression analysis. As mentioned in Chapter 4, the dependent variable consisted of interruptions initiated by others, and independent variables were the average visibility of potential work areas with work-surfaces, the average integration value (accessibility), and the walking distance. These were measured by segments of paths that nurses took from a medication station to patient rooms.

Initial analysis that was described in the previous chapter did not show expected results that are related to the hypotheses. The technique of analyzing segments of paths that were divided by visibility of potential work areas might have been too refined to reflect the actual experience of nurses. In fact, the observations results were significantly different between wings and overall layout of wings seemed different, subsequently the entire path was used as a unit of analysis. However, the analysis based on the entire path did not show any significant effect. The third analysis used segments based on visibility to potential work areas only in nurse stations without substations as the unit of analysis, and this showed significant prediction.

5.2 Interruptions

In this section, I describe how the nature or content of interruptions differs by location, the frequency of interruptions, and the initiators of interruptions. The basis of this discussion is primarily the 32 observed events that included both self-initiated interruptions and those initiated by others (Table 3.1). Overall, interruptions happened regardless of medication administration process and even the nurses themselves who are retrieving medications initiated interruptions during the task, which supports assumptions made in Section 4.2.

Table 3.1 Characteristics of Interruptions Observed

Category	Content % (count)		Location% (count)		Source% (count)	
Interruptions Initiated by Both Self and Others (32)	Work-related	63% (21)	Substation and Patient Room	31%(10)	Self-initiated	41% (13)
			Nurse Station	38%(12)		
	Private	25% (8)	Hallway	31%(10)	Others-initiated	44% (14)
Only Interruptions Initiated by Others (14)	Work-related	57% (8)	Substation and Patient Room	21%(3)	Self-initiated	0% (0)
			Nurse Station	43%(6)		
	Private	43% (6)	Hallway	36%(5)	Others-initiated	100% (14)

5.2.1 Content and Location

Among 32 interruptions, 63% (21) were work-related conversations, but none of them were related to medication administration and 25% (8) were private conversations, and for 14 interruptions initiated by others, 57% (8) were work related and 43% (6). The percentage of private conversations is higher than in other studies but I only considered person-to-person encounters as interruptions, while other studies included non-personal interruptions such as alarms or seeking equipment, which might have contributed to the lower percentage of interruptions of a private nature. The ratio of work-related and private conversation as interruptions seemed to differ by around locations: substation and patient room versus nurse station and hallway.

5.2.1.1 Around Substations and Patient Rooms

Based on the 32 observation results, interruptions around substations and patients were mainly work-related, and out of 10 interruptions only one was private conversation. These interruptions tend to be more work-related because other caregivers such as physicians, nutritionists, and therapists come to the substations or patient rooms to give care to the patients and this might be an opportunity for nurses to talk with them or for them to talk with the nurse about the patient. A nurse typically stays around a patient room because they need to monitor their patient, but other caregivers are not stationed around there and they come because they need to work on patients. This is probably why many interruptions were work-related around substations and patient rooms.

Drawing "3" in Figure 5.1 shows that a nurse initiated a private conversation with a nurse practitioner who was at the nurse station (inp2=45s, Table 4.2) and then initiated work-related conversation with a nurse who was at the next substation (in1=30s). Conversation with the nurse practitioner at the nurse station might have been work-related if the nurse practitioner or the nurse planned it, but that was not the case. The nurse practitioner needing to talk to the nurse regarding patient care, would probably go to the substation to find the nurse. The nurse at the substation was interrupted by the nurse who was getting medications and the interrupting nurse fulfilled a need for communication with the nurse in close proximity. The interrupting nurse might not have created an interruption if the location of the interrupted nurse was in one of the patient rooms, but since the interrupted nurse happened to be at the substation the interrupter probably talked to the interrupted nurse because of convenience and proximity.

In drawing “5” in Figure 5.1, a nurse was interrupted by a physician around the nurse station briefly and then another conversation about work-related issues continued near the patient room as they walked into the patient room together. It cannot be verified, but the physician might have already had in mind that he was going to talk to the nurse or the physician was reminded of something by seeing the nurse. In either case, the physician needed to talk to the nurse about the patient, and he started talking about the patient after a pause as they went into the patient room together.

5.2.1.2 Around Nurse Stations and Hallways

Half of the interruptions, six out of twelve, around nurse stations were private conversations (Figure 5.2). In contrast to substations, other caregivers at nurse stations were probably not expecting nurses who were passing by nurse station on the way to a patient room after getting medications. That might be the reason why there were relatively more private conversations in nurse stations. If this finding is confirmed by future studies, it supports the recommendation for reducing visibility to the nurse station for nurses on medication administration trips. Self-initiated interruptions for work-related conversations might have been planned by nurses who were getting medications but this could not be verified. Four out of ten interruptions in hallways were private conversations (Figure 5.3). Like the conversations of caregivers at the nurse station, the participants in these private conversations might not have expected to see nurses who were getting medications in hallways. While other caregivers might have been on the way to talk to the nurses, this was not verified in this thesis.

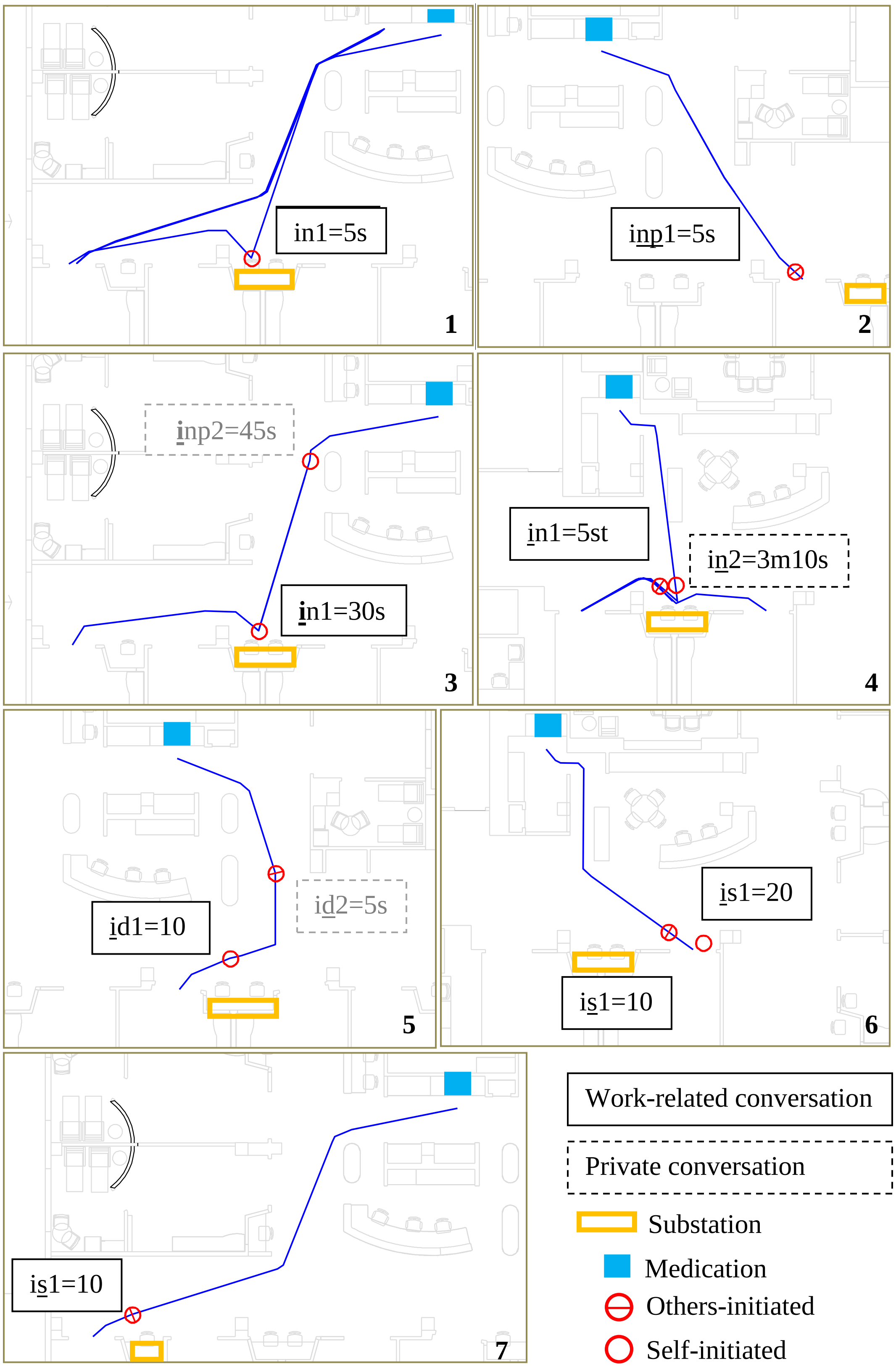


Figure 5.1: Interruptions around Substations and Patient Rooms: Work-related Conversations

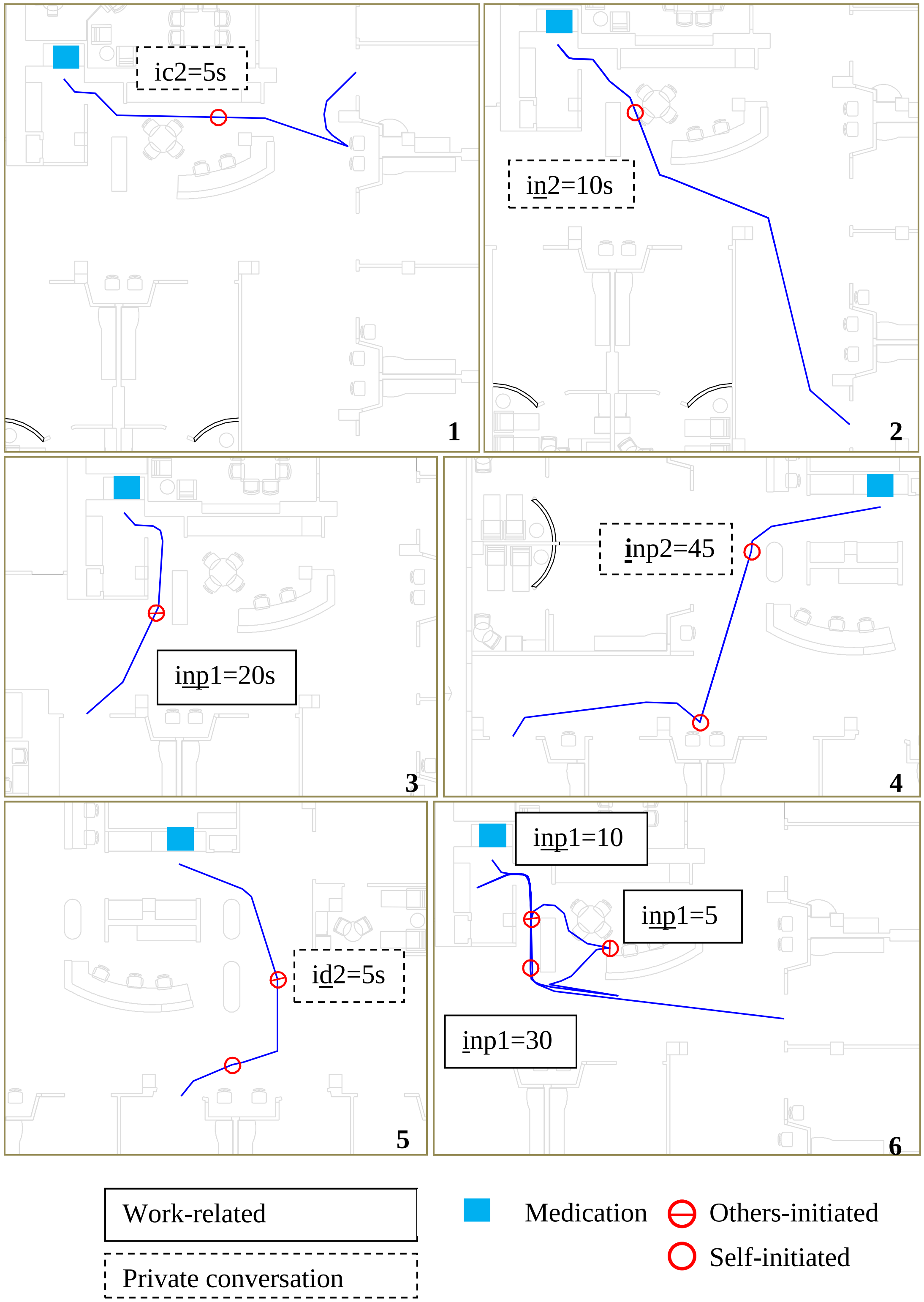


Figure 5.2: Interruptions around Nurse Stations: Work-related and Private Conversations

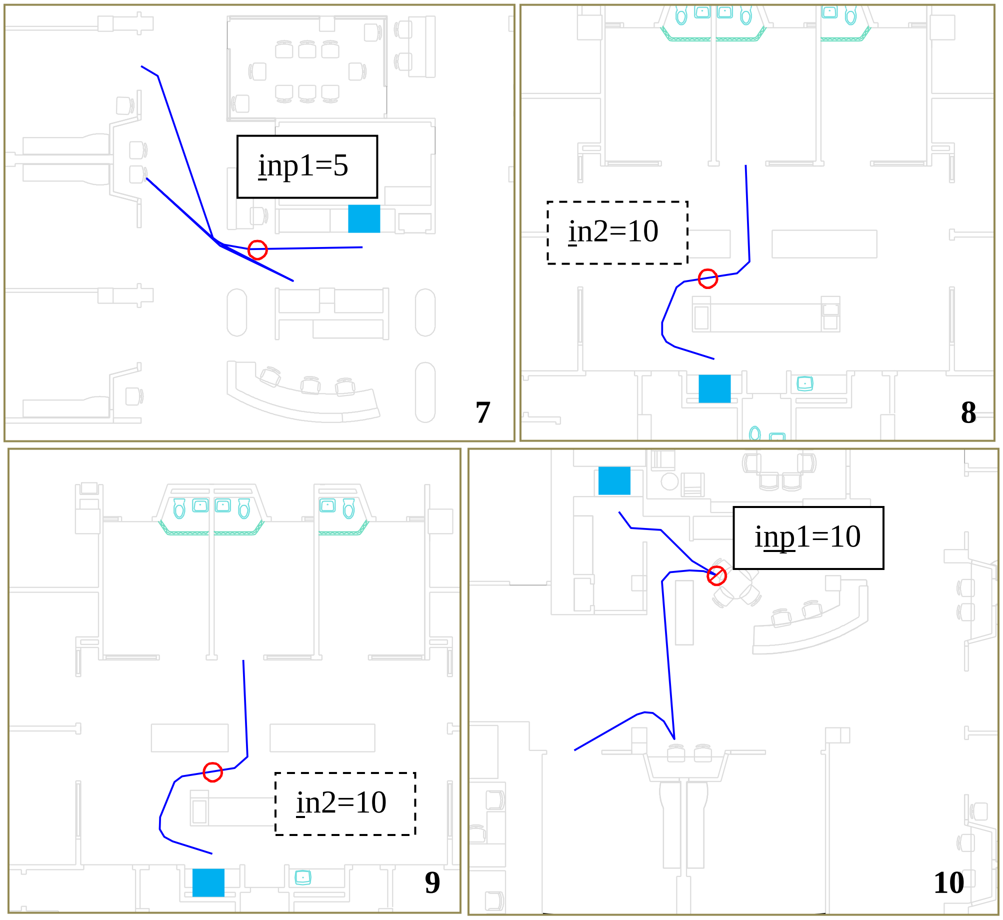


Figure 5.2(*Continued*): Interruptions around Nurse Stations: Work-related and Private Conversations

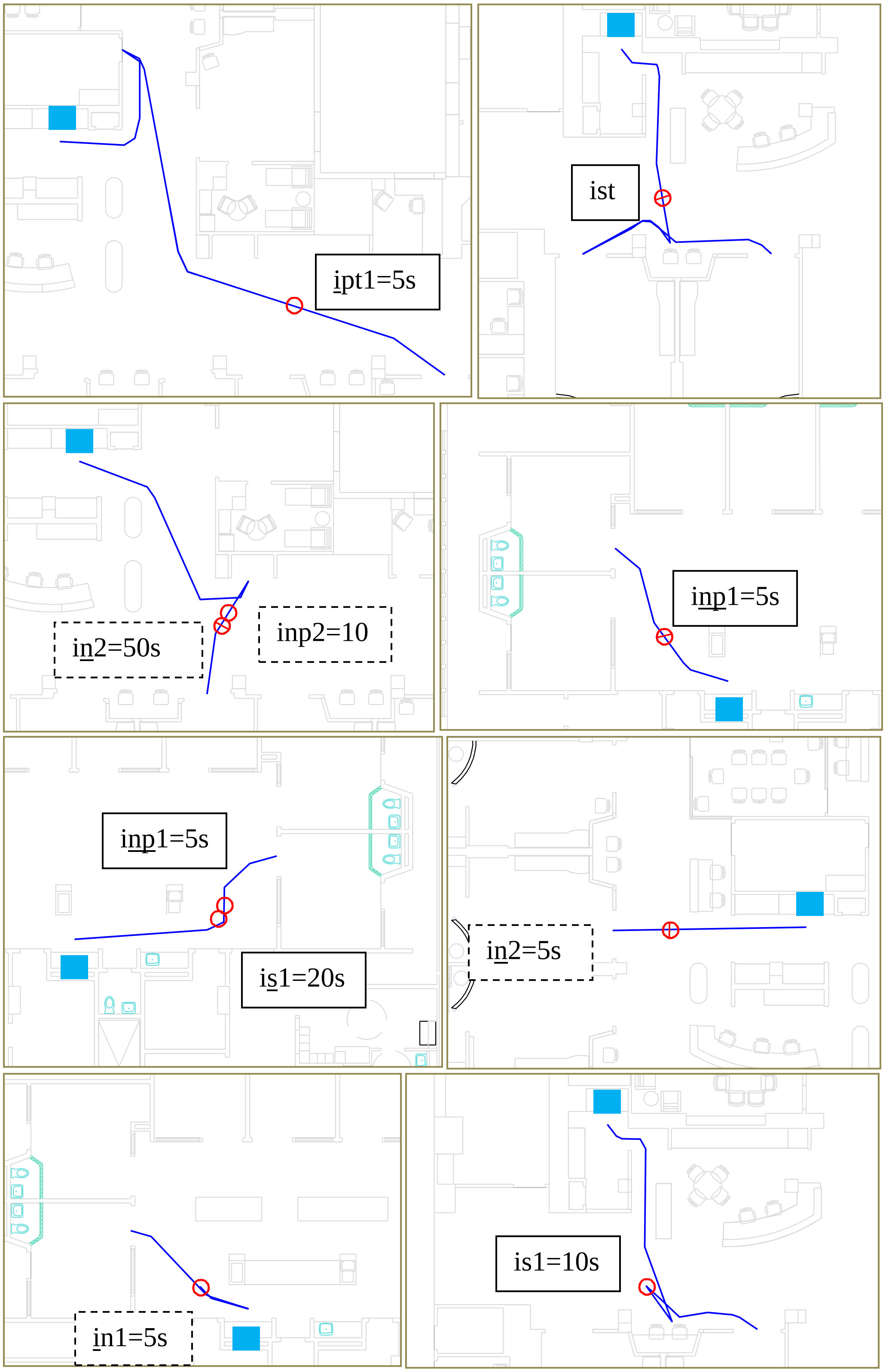


Figure 5.3: Interruptions in Hallway: Work-related and Private Conversations

5.2.2 Frequency of Interruptions

Interruptions happened 32 times in 83 medication trips. These interruptions were initiated by both nurses themselves and others and do not include the ones occurring around the medication station. Given the 36 second average walking time per trip from the medication station to a patient room and 0.386 interruptions per trip, it came down to 0.643 interruptions per minute or 39 interruptions per hour, which is much higher than what other studies have found. Other studies have found in the range of 3 to 11 interruptions per hour as shown in Chapter 3.

In fact, studies seldom limited observation to only when nurses are walking around, which might be the reason for the difference. In office settings, Penn and colleagues (1999) mentioned that getting up from workstations and walking around were thought of by others as making a person "available" for conversation, and this might have been the case in health care as well. Walking to get medication means they are in hallway, which is public space within a unit, and they might have been much accessible by others. People might be less likely to interrupt someone who is engaged in a task especially in sitting position. Other studies observed nurses were not only walking but also doing other activities and tasks. If future studies also find the similar result of a higher interruption rate while nurses walk around, nurses' walking distance should be shortened not only for fatigue but also to reduce interruptions and potential errors.

5.2.3 Source of Interruptions

Interruptions were initiated by the nurses themselves 41% (13) of the time and by others 44% (14) as far as observation could differentiate. Among interruptions initiated by others, ones initiated by other nurses constituted 29% (4) of the total, nurse practitioners 43% (7), physicians 7% (1), and other staff 7% (1). This did not include interruptions around the medication station. Self-initiated interruptions were a bit higher than other studies that found 5% to 21% as shown in Table 3.1. In fact, other studies were mostly conducted in non-ICU environments and nurses in these studies might have had four to six patients at a time compared to two patients per nurse in the units observed for this thesis. Also, nurses in other studies might have had more sources of information and more interruptions they needed to deal with because of higher number of patients.

In addition, although other studies have not mentioned the size of the unit or patient room, 20 out of 27 patient rooms studied in this thesis had larger patient rooms with family areas compared to the industry average. This might have resulted in a larger unit size and lower density of staff in a given area, which might have contributed to the low percentage of interruptions initiated by others. Other studies had 50-70% of interruptions initiated by others (compared to 44%) if they differentiated between interruptions by self and others. In addition, the studies included interruptions by sources other than people, such as phone and alarms, which I did not record. However, the unit with small patient rooms, 2G, in this thesis did not have higher rate of interruptions. The effects of the number of assigned patients per nurse and the density of staff in a given area on interruptions initiated by others have not been verified by this thesis. After all, a higher percentage of interruptions by others might suggest that the physical environment can potentially affect interruptions, especially those that happen due to chance encounters, because the physical environment can determine accessibility and visibility to and from others.

5.3 Analysis Based on Segments by i-Partition

While it may be true that nurses perceive their spatial experience based on the entire path of a medication trip, not every part of the path might have effects on interruptions, so nurse's paths from medication room to a patient room were divided into segments as discussed in Chapter 4. Every variable was measured by using these segments. Independent variables included the average visibility of potential work areas that included work surfaces of nurse station and substation (this is the colored area around potential work areas in Figure 4.1), the average integration value that is acquired from an analysis of the floor plan with the Depthmap program, and segment length. Examples of visibility analysis (Figure 5.4) and visual integration (Figure 5.5) analysis graphs created by the Depthmap program are shown below with red indicating higher values and blue indicating lower ones. Segment length was measured by counting the tiles in each segment on the analysis graphs, and one tile was approximately one square feet.

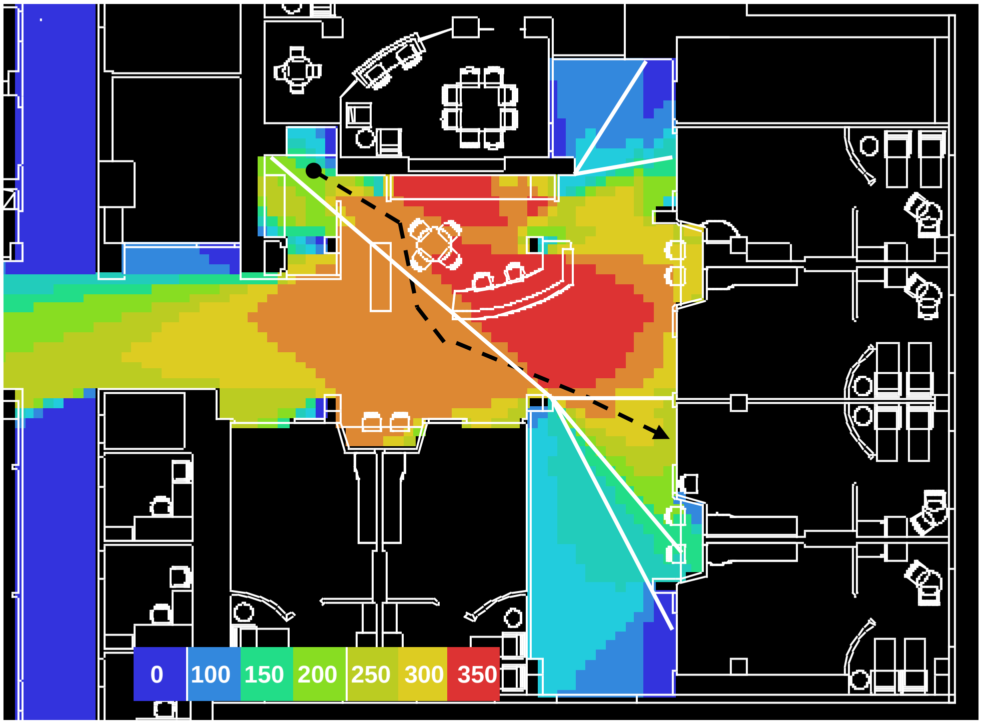


Figure 5.4: Visibility Analysis by Depthmap Program and i-Partition: Measurement for Segments

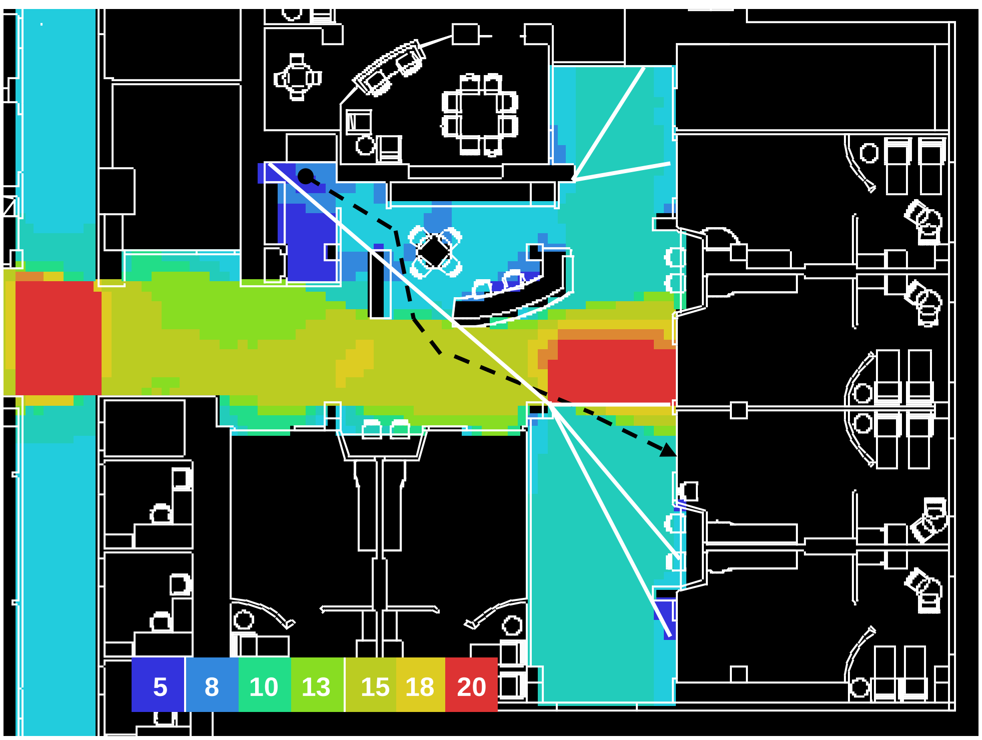


Figure 5.5: Integration Analysis by Depthmap Program and i-Partition: Measurement for Segments

The dependent variable was, as mentioned earlier, the number of interruptions by others for each segment. From 83 medication trip observations, 318 path segments were created with the i-Partition lines. All three independent variables were used to test a Poisson regression model:

Log (no. of interruption) = B1 (visibility) +B2(length) + B3(integration) +B

The statistical analysis was done with the SPSS computer statistical analysis program. This model was fit to predict number of interruptions ($p = .003$) but did not show expected results as shown in Table 5.2. In particular, the visibility value showed negative contribution (B= -.005) to the number of interruptions.

Table 5.2: All Variable Estimates for i-Partition Segments by Nurse Stations and Substations

			95% Wald Confidence Interval		Hypothesis Test		
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2.776	.5785	-3.909	-1.642	23.023	1	.000
Visibility	-.005	.0023	-.010	-.001	5.287	1	.021
Length	.045	.0153	.015	.075	8.752	1	.003
Integration	.117	.0512	.016	.217	5.207	1	.022
(Scale)	1[a]						

The unexpected results might have been due to segments being too refined to reflect nurses' experience. For example, a nurse might have seen or been seen by others in one segment but then interrupted in next segment or the one after that, because nurses are in motion to deliver medications to patients. Segment length also showed significant effects, and the longer the segment the more interruptions took place, perhaps simply because there was a longer opportunity for an interruption to occur on a longer segment than a shorter one. However, this explanation has not been verified.

Interestingly, comparisons showed significant differences between unit wings (Table 5.3), and this suggests that the effects of design are different between wings. One difference might have been hallway layout. 2D West has relatively longer hallways compared to 2D East and 2G, and there is no hallway that is not attached to a nurse station in 2G. This must have affected the visibility of the nurse station along each path, because a nurse who walks in the hallways that are not next to a nurse station must have lower visibility from the nurse station than in hallways next to nurse station. The design differences between wings are shown in Fig 5.6. Further, both East and West wings of 2D ICU had one substation attached to every two patient rooms, which was not consistent with the findings of differences between wings. In addition, the substation closest to a nurse during a medication trip was often their own substation, and it was typically vacant. Therefore, the visibility from substations might not explain differences between wings.

Table 5.3: Between Wing Comparison for the Number of Interruptions (ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
Int	Between Groups	2.391	2	1.195	5.857	.003
	Within Groups	63.673	312	.204		
	Total	66.063	314			
Intother	Between Groups	.865	2	.432	4.031	.019
	Within Groups	33.465	312	.107		
	Total	34.330	314			

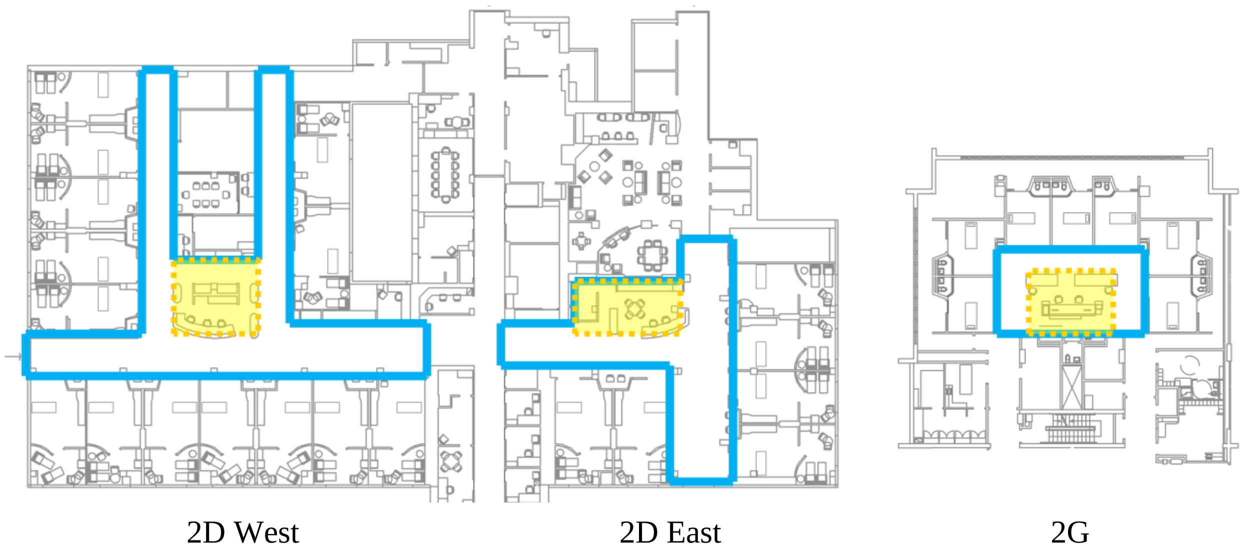


Figure 5.6: Unit Wing Layout: Different Shape of Hallways

5.4 Analysis Based on the Entire Path

Given that comparisons between wings showed significant differences, visibility of substations might not be relevant to the observed interruptions because the visibility is similar across the two wings of 2D ICU. Therefore, analyzing visibility to nurse station potential work areas without substation might reflect differences between wings. Each wing had only one central nurse station and nurses' paths from the medication station in the central area to patient rooms might have resulted in different levels of visibility to nurse station in each wing. This might be reflected by the nurses' spatial experience of the entire walking path during medication administration, rather than by the segments of path. The entire path is from the medication station to a patient room. Therefore, I used the entire path as a unit of analysis, given that segment analysis did not show expected results. Visibility of potential work area areas in nurses' stations was measured for this analysis, and integration and distance measurement was done in the same way as in segment analysis. A Poisson regression model was tested.

Log (no. of interruption) = B1 (integration) +B2 (visibility) + B3 (length) +B

The results did not show significant prediction of the model ($p = 0.313$) and no variable had significant effect as shown in Table 5.4. The entire path might be a conventional unit or dimension for describing medication trips of nurses who might perceive their spatial experience as an entire path of a task, but analyzing the entire path might have had actually cancelled out different levels of effects in various parts of the path, as mentioned earlier, and this was the reason for using i-Partition segments to reflect the different levels of the effects on interruptions in different parts of a path.

Table 5.4: All Variable Estimates for the Entire Path

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.353	2.2638	-4.790	4.084	.024	1	.876
Integ	-.218	.2147	-.638	.203	1.027	1	.311
VisToNSwholepath	.017	.0112	-.005	.039	2.355	1	.125
DistWhole	-.035	.0296	-.093	.023	1.428	1	.232
(Scale)	1[a]						

5.5 Analysis Based on i-Partition by Visibility to Nurse Station

Since the analysis of the entire path as a unit of analysis did not result any significant discoveries, I brought the segment idea back into the analysis, but drew i-Partition lines based on potential work areas in nurse stations not substations, as shown in Figure 5.4. Again a Poisson regression model was tested:

Log (no. of interruption) = B1 (visibility) +B2 (length) + B3 (integration) +B

The overall model showed a significant prediction (p=0.03) but each variable did not show a significant effect, as seen in Table 5.5.

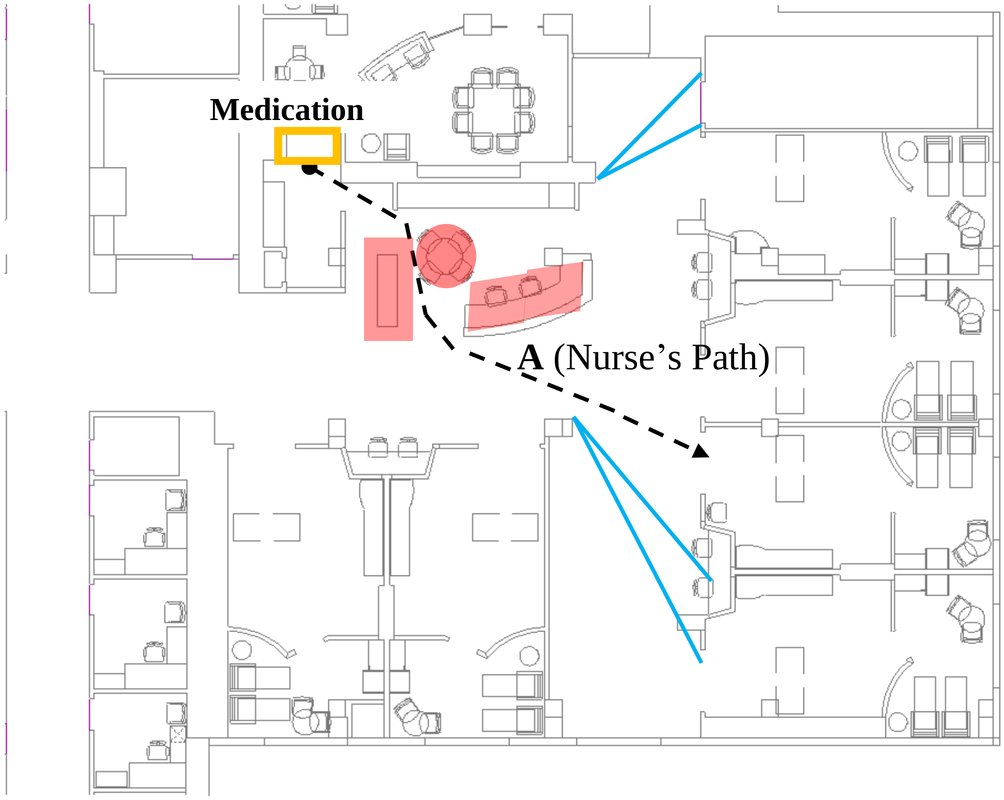


Figure 5.8 i-Partition Based on Visibility to Potential Work Areas in Nurse Station Only

Table 5.5: All Variable Estimates for i-Partition Segments by Nurse Stations

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-4.698	1.3902	-7.423	-1.974	11.423	1	.001
NurseStVis	.016	.0119	-.007	.040	1.871	1	.171
Length	.023	.0270	-.029	.076	.756	1	.385
Integration	-.002	.1907	-.375	.372	.000	1	.994
(Scale)	1[a]						

Next, the analysis tested the model without the integration value that showed the least significance (p=.994), and the result showed improved significance (p=0.011 from p=0.03), but no variable was shown to have significant effect (Table 5.6)

Log (no. of interruption) = B1(visibility) +B2(length) +B

Table 5.6: Variable Estimates without Integration for i-Partition Segment

			95% Wald Confidence Interval		Hypothesis Test		
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-4.705	1.1087	-6.878	-2.532	18.010	1	.000
Visibility	.016	.0088	-.001	.033	3.390	1	.066
Length	.023	.0236	-.023	.070	.978	1	.323
(Scale)	1[a]						

Another analysis tested a model that included the effect of interactions between visibility and segment length to see if this interaction might have an effect. Interaction was not significant (p=0.396) and it actually reduced significance of the overall model (p=0.022 compared to p=0.011 without interaction) as shown in Table 5.7.

Log (no. of interruption) = B1 (visibility) + B2 (length) + B3 (visibility*length) + B

Table 5.7: Variable Estimates for i-Partition Segments with Interaction of Visibility and Length

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	-6.432	2.4872	-11.307	-1.557	6.688	1	.010
Visibility	.030	.0194	-.008	.068	2.348	1	.125
Length	.118	.1118	-.101	.337	1.113	1	.291
Visibility * Length	-.001	.0008	-.002	.001	.719	1	.396
(Scale)	1[a]						

In fact, testing only visibility to potential work area areas in nurse station showed improved significance (p= 0.005) as shown in Tables 5.8 and 5.9.

Log (no. of interruption) = B1 (Visibility) + B

Table 5.8: Overall Model Test for i-Partition Segment with Visibility

Likelihood Ratio Chi-Square	Df	Sig.
7.981	1	.005

Table 5.9: Visibility Variable Estimates for i-Partition Segments

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	-4.617	1.0761	-6.727	-2.508	18.411	1	.000
NurseStVis	.020	.0077	.005	.035	6.608	1	.010
(Scale)	1[a]						

Therefore, given this series of analyses and within the limits of the variables I tested, visibility from potential work areas in nurse stations showed the most significance in prediction of the number of interruptions that were initiated by others.

5.6 Discussion

5.6.1 Findings for the Hypotheses

The findings of this dissertation might be improved by verifying the conditions of the physical environment that I focused on, and each variable is discussed below. In addition, understanding the findings could be also improved by considering specific conditions other than the physical environment that may influence interruptions. These conditions include the nature of medication tasks in neurological ICUs and interruptions that were initiated by others, which were not specified in the hypotheses. Another condition or limitation of this study is that I only observed trips from a medication station to a patient room instead of trips going back and forth between the two locations. Testing of my hypotheses by observations was not conducted for either medical-surgical unit nurses or for all of the activities of nurses. However, as discussed in Chapter 3, if nurses were interrupted by others during medication administration, it is likely that they will be interrupted while doing other tasks, because medication administration is a task that is not supposed to be interrupted.

5.6.1.1 Visibility

The hypothesis that related visibility to interruptions was supported by observation data with specific conditions imposed on the visibility variable. Visibility was not for or from everywhere but rather the visibility was from the potential work areas with horizontal surfaces in nurse stations not including substations. The visibility data actually predicted the number of interruptions by others, which might mean that other staff members were present in or around the nurse station and they interrupted the observed nurses. The nurse station is a shared space with work areas and surfaces and it might have higher density of people than a hallway, and staff in there might be more likely to interrupt others than, for example, staff in patient rooms, who might be occupied with a patient. Given these conditions, the hypothesis regarding visibility might be restated as below following the original one:

- Nurses will be interrupted more frequently when they are in areas where they can see others and are seen more easily by others
    - During the medication trips of ICU nurses from a medication station to a patient room, nurses will be interrupted more by others when they are in the areas where the nurses are more visible from potential work areas (with horizontal surfaces) in the nurse station.

5.6.1.2 Accessibility

The hypothesis that related accessibility to interruptions was not supported. Accessibility was measured by the integration value, which is average number of turns needed to travel from a space to all other spaces as discussed in Chapter 4. The analysis did not include patient rooms or rooms for supplies and other services, the doors of which were typically closed. The integration value predicted the interactions well where people moved around relatively freely but the scope of this thesis was limited to a predetermined task path, which inherently limits the free movement of people. This will be further discussed in Chapter 6. These limitations might also include a lower density of moving people compared to movement in other settings such as offices where integration value well-predicted interactions. Given these, the hypothesis is restated as below

- Nurses will be interrupted more when they are in areas that are more accessible (reachable with fewer turns) by others
    - During the medication trips from a medication station to a patient room in the neurological ICUs where the density of people is low and the free movement of people might be limited because of the tasks, nurses were not interrupted more where there was higher accessibility to a hallway and other shared spaces such as a nurse station.

5.6.1.3 Distance

The hypothesis that related walking distance to interruptions was not supported by the analysis. In hospitals, people get exposed to areas such as nurse stations where there is a greater chance of interruptions as they walk around a unit. Exposure to such areas might have mattered more than duration of exposure because they can walk in a hallway where not many other people are present.

- Nurses will be interrupted more when they need to walk farther to do their tasks, because they get exposed to other people for longer periods of time.
    - During medication trips of ICU nurses from a medication station to a patient room, nurses were not interrupted more by others when they walked longer distances.

5.6.2 Unit of Analysis

A series of analyses provided lessons for determining the unit of analysis for nurses who are doing a task that requires moving through space. If nurses had not been moving, the unit of analysis might have been further refined as much as the initial i-Partitions that were drawn based on visibility of potential work areas in both the substation and the nurse station, but this cannot be verified in the thesis. Initial i-Partition lines could have been even further refined if other points or features of potential work areas were used for drawing the partition lines, such as the point where the entire area is visible, in addition to just the first visible point of the area. Even determining segments for rather static participants might require multiple steps of analysis to find the appropriate unit of analysis. There is no clear way to determine in advance the unit of analysis for walking or standing participants. Significant outcome variable differences between wings with refined initial segments guided this chapter to use only nurse station for potential work areas and to find the unit of analysis, and similarly relevant analysis to outcome variables might provide ways to determine the unit of analysis that reflects effects of variables better

CHAPTER 6

DISCUSSION AND CONCLUSION

The physical environment affects interruption events (Oldham, et al., 1995) and this fact suggests that some tasks might be more “interruptible” because they are highly visible and physically easily accessible. For critical tasks, these conditions might result in detrimental errors because of interruptions. Medication administration is a task where nurses are exposed to others as they walk to and from a medication station, and errors are unlikely to be preventable during this stage of the process, so that the errors are very likely to affect patients.(Joint Commission on Accreditation of Healthcare Organizations (JCAHO), 2006) Through redesign of work practices with support of spatial configuration, high risk tasks might become “interruption resilient”(Westbrook, et al., 2010).

In studies of architecture, interruptions are rarely discussed, as mentioned in Chapter 2. Therefore, one contribution of this thesis is introducing interruption as a subject of interest and a perspective for chance encounters in addition to non-interrupting communication interactions. Furthermore, findings of this thesis help us understand when we might need to view chance encounters as interruptions or interactions.

As methodological contributions, in the following section~~,~~ visibility and integration are compared to ~~understand~~ better explain when each measure might best be used. This ~~discussion~~ comparison is based on findings from an analysis of the quantitative measurements of ~~these~~ visibility and integration variables as they ~~that~~ were linked to a behavioral variable, interruption. In addition, this thesis examined the idea of using the “i-Partition” technique to ~~that~~ define~~d~~ areas ~~by~~ according to the visibility ~~to~~ of specific features ~~was empirically examined~~ to see whether the areas defined by i-Partition ~~areas~~ reflected ~~the~~ human behavior~~, which~~. This has not been done by other studies

Two specific conclusions were made based on observation and data analysis. The average visibility of potential work areas in nurse stations significantly contributed to nurses' interruptions that were initiated by others during medication trips from a medication station to a patient room. Another conclusion is that spatial experience for a task such as medication administration might be perceived or described by the entire trip path, but analysis of the entire path as a unit did not reflect interruption events that nurses experienced. Not every part of the path had effects on interruptions. Instead, segments of the path that are divided by visibility reflected the interruptions events during the medication trip. This is also related to lessons learned that the unit of analysis should be chosen carefully to identify the effects of the physical environment as described in Chapter 5.

Based on the first conclusion, the design implications are examined, and an alternative medication station is proposed for the unit under study, one that reduces interruptions and supports patient monitoring. The predicted risk of at least one major clinical error with interruptions is discussed as a test and limitation of prediction is described. I describe characteristics of interruptions observed: Contents, frequency, and sources and suggest future directions for studies.

The culture of interruptions should be noted in this discussion, which was that nurses were usually willing participants in the observed interruption events. A substantial percentage of self-initiated interruptions (41%) and private conversations (25%) observed for this study might confirm the findings from the research literature review in Chapter 3 and assumptions in Section

4.2, which states that nurses do not mind interrupting others and getting interrupted. It seemed that nurses did not want to offend others by not properly responding to them. They did not seem to avoid interruptions during medication administration, and they might even feel obligated to talk to others when others are nearby so that they do not offend others by not conversing with them. These facts support the importance of the role of the physical environment, because healthcare workers might tend to interrupt each other more if they see each other or are nearby. It also suggests that the culture of practice does not acknowledge the seriousness of the impact of interruptions. In addition, nurses did not seem to exercise any management strategy when they got interrupted. Interrupting conversations typically went on seamlessly. Based on observation results, I did not see any nurse who told interrupters to wait until medication administration is finished or tried to reduce memory load by, for example, writing things down.

6.1 Integration versus Visibility

Integration value did not seem to contribute significantly to observed interruptions, which was unexpected given that the integration value predicted movement and interaction of people in various settings of different culture and scales (Bafna, 2003; Penn & Desyllas, 1999) (Bafna, 2003; Penn & Desyllas, 1999) (Bafna, 2003; Hillier, 1996b; Penn & Desyllas, 1999). Comparison between the location of interruptions and the integration value (Figure 6.1) showed overlap between the red areas of high integration value and interruptions, but there were still many other interruptions that were not in the red areas. In addition, many interruptions happened in and around nurse stations, but integration values were not very high in the nurse stations.

Several factors might be considered to explain this discrepancy. What if there were many more people working in the units, or in other words, what if the density of people was higher?

Would it have made a difference? In fact, previous studies were conducted in office settings that might have had more people in a given space (Figure 6.2). If we imagine that office workstations filled all the areas other than hallways in the units studied, we would expect for there to be a higher density of people in these units. There might not have been enough density of movement to increase interruptions/interactions around high integration value areas (Penn & Desyllas, 1999). In addition, nurses had to stay where they can monitor patients while people in the office studies did not stay in their workstations 50-70% of the time according to the previous studies in office settings (Penn & Desyllas, 1999). This fact must have contributed to the density of people in motion. In fact, the previous studies have not discussed conditions where there is a low density of people, probably because the examined settings had larger floor areas with many more employees than settings examined for this thesis.

Another factor might have been the movement path for tasks such as trips between a patient room, a substation and a nurse station, medication room, and other service areas which are directly related to patient care tasks. These pre-determined complex functional routes in health care settings might have restricted free movement of people more than in the office settings. However, the effects of density and movement for tasks are beyond the scope of this study.

Integration reflects highly accessible areas such as hallways, and people in these areas are already out of their work stations and might be standing, walking and more willing to talk. Therefore, integration might be more useful than visibility to predict interactions (positive encounters). On the other hand, visibility might be more useful than integration to predict encounters that involve people who are anchored, meaning seated or engaged in certain activities in their workstations or some other specific location. This is especially true when the visibility is specified to the location or workstations where the people are seated, similar to visibility of potential work areas in this thesis. When conversation occurs across someone's workstation or office cubicle, it has a better chance of becoming an interruption than conversation in a hallway, because workers in personal areas are likely to be working on tasks, and these personal work areas might not be in areas of high accessibility and integration value is relatively lower than hallways. I show that the level of visibility of potential work areas in a nurse station actually predicted interruptions, and that most of the interruptions happened around nurse stations (40%) and substations (28%) where seating is available, compared to hallways (32%).

Therefore, although further verification is needed, this thesis proposes that visibility might be more useful measure than integration for interruptions while integration might be more useful for interactions. In relation to this, either measure might be more likely to be related to certain social conditions, for example, visibility to work station might be used to predict interruptions with employees of high levels and complex tasks (Table 6.1). Employees of high levels and with complex tasks might be more likely to feel interrupted with chance encounters especially when they are in their work stations as mentioned in Chapter 2. On the other hand, even for employees at high levels, integration might be used to predict their positive encounters (interactions) but this is not verified either. As shown in Table 6.1, visibility might also work better than integration to predict encounters in a setting where there is a low density of moving people and when people involved in encounters are anchored to a location. These conditions need to be further examined by future studies.

In the study by Rashid and colleagues (2006), the visibility of people from the observation path rather than integration predicted the number of interactions in a setting where most of employees were professionals. The study assumed encounters as positive communications but no content of the interactions were described, while I speculate that many observed interactions might have been interruptions to the professionals in the study. In addition, as mentioned earlier, chance encounters are more likely to be viewed as interruptions instead of positive interactions for professionals and managers compared to employees in clerical positions. Verification of task type for employees observed in the study might also help better understand characteristics of the encounters. One study found that the integration value predicts interactions in companies that encouraged interactions for success of their marketing concept (Penn & Desyllas, 1999).

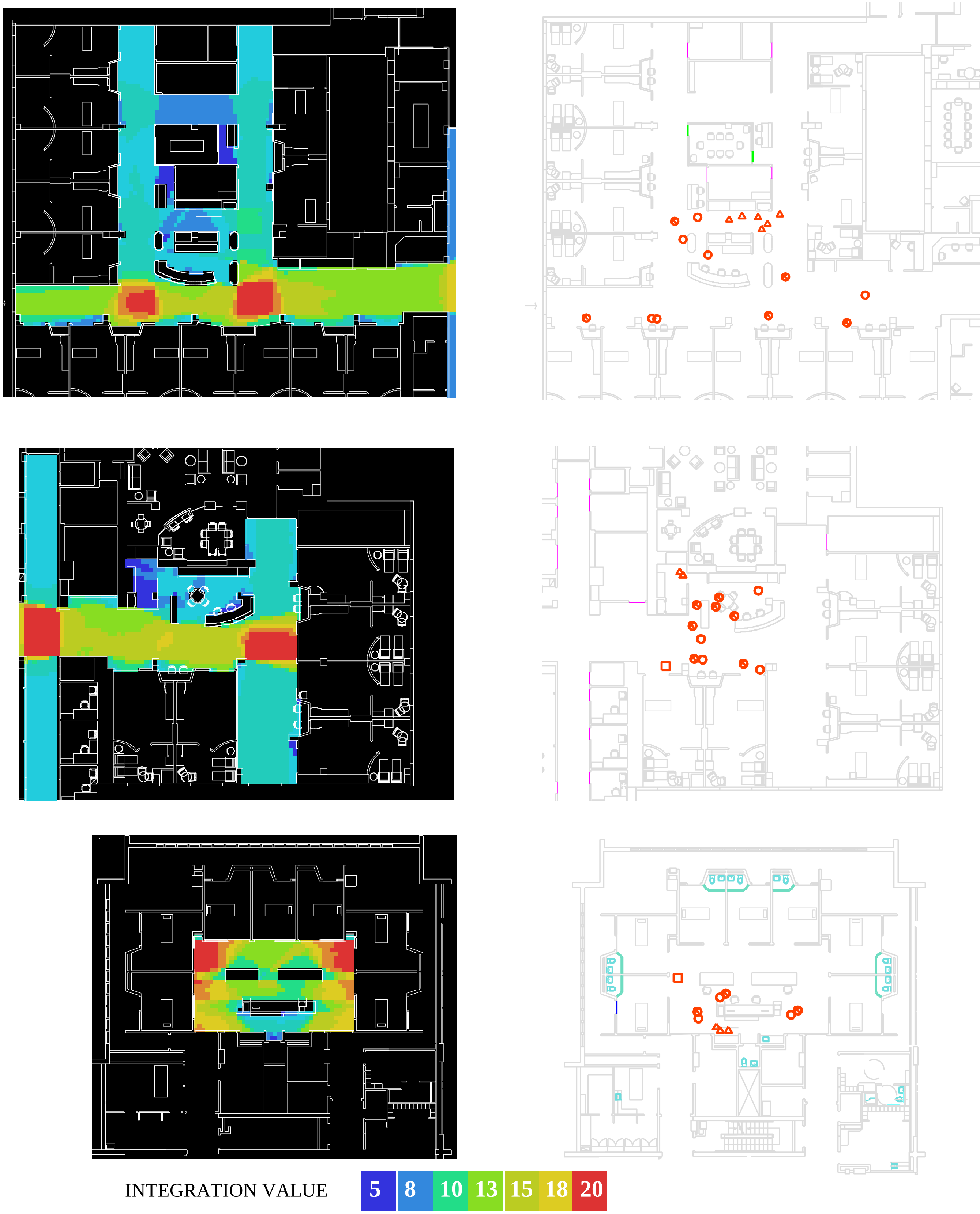


Figure 6.1 Integration Value and Interruption Location: Mismatch

Table 6.1: Proposed Conditions for the Use of Visibility and Integration: Interruptions versus Interactions

Measure		Visibility to source of encounters	Integration
Suggested Encounter Type to be Predicted		Interruptions (negative)	Interactions (positive)
Proposed Conditions for Measure	Physical	• Low density of moving people • Involves people seated or engaged in a task	• High density of moving people • All parties are moving or standing
	Social	• People with high level positions, professionals and managers • People with complex tasks	• People with low level positions, clerical positions • People with simple tasks • Research and development

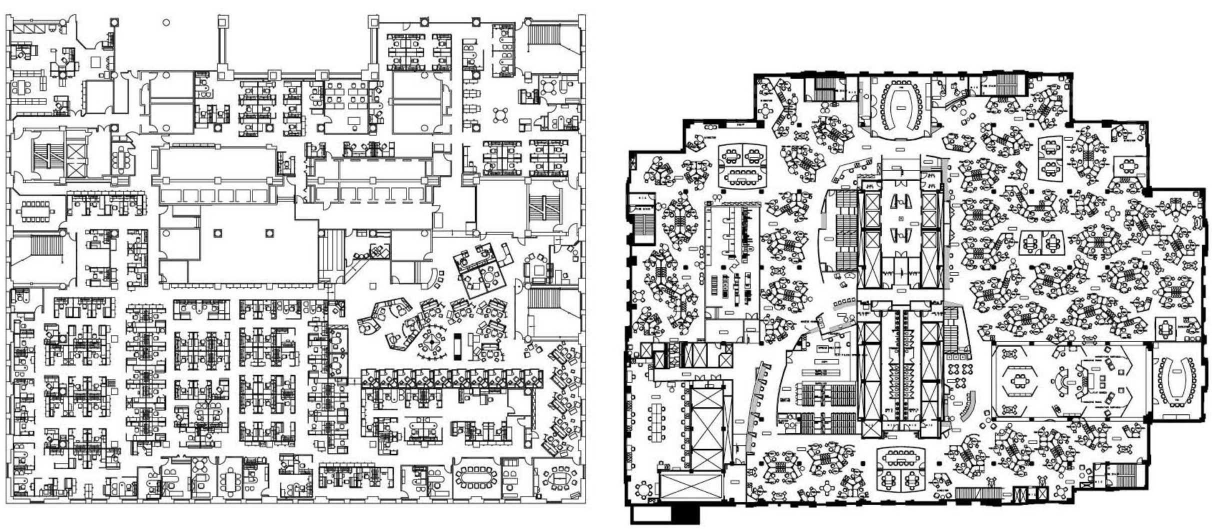


Figure 6.2 Floor Plans from Previous Studies in Architecture (Rashid, 2009): Larger Size and Higher Density of People

6.2 Design Implications

Many hospital units are designed to put a nurse station and medication station together, including the three unit wings studied in this thesis as shown in Figure 6.3. However, having the medication and nurse station together makes nurses go through or nearby a nurse station, which will increase the visibility of a nurse station, which is predicted to increase the number of interruptions based on the observations of this thesis.

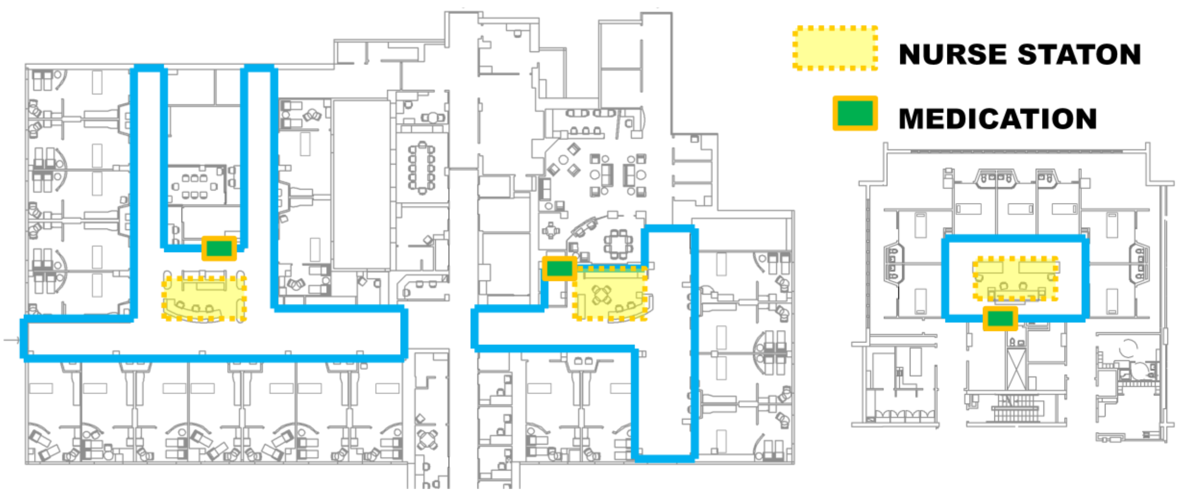


Figure 6.3: Location of Nurse Station and Medication Station: Side by Side

What if there was a design alternative for the medication station for some patient rooms, such as in the center example (2D East) of Figure 6.3 as shown in Figure 6.4. I chose this location because of the reduced visibility of the nurse station. This will result in a different walking path for patient rooms (from 41 to 44) as shown in Figure 6.5. Analysis of alternative paths showed decreased visibility to the nurse station while improving visibility to the patient bed for monitoring as shown in Figures 6.6 and 6.7. Only the first segment from the medication station is counted for patient room "44." The value from the existing path is shown in the blue columns and the alternative in red. Furthermore, an equation can be written based on the analysis in Table 5.8 from Chapter 5: $y = e^{.02x - 4.617}$

In the equation, "x" is average visibility to potential work areas (areas with work surfaces) in the nurse station and "y" is the predicted number of interruptions by others. Given this equation, I calculated the predicted number of interruptions by others for each trip as shown in Figure 6.8.

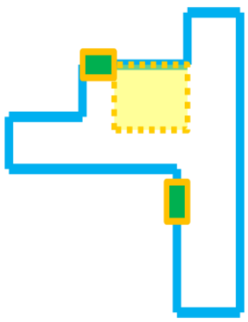


Figure 6.4: Alternative Medication Station

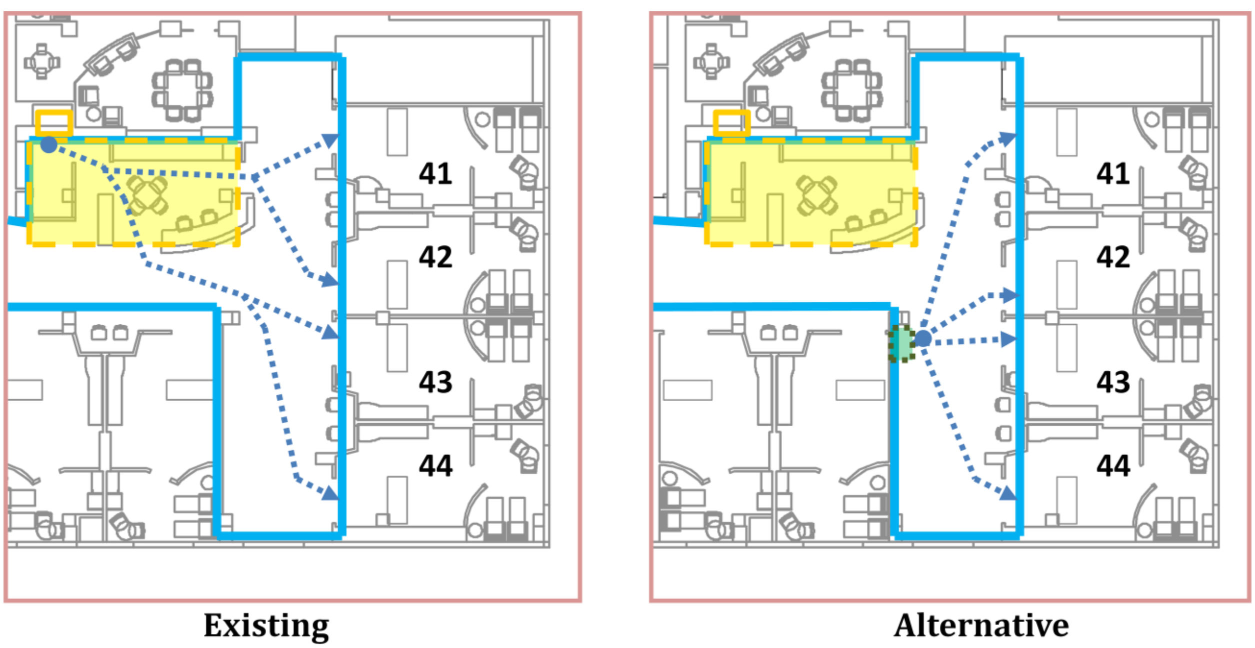


Figure 6.5: Change in Walking Path with the Alternative: Less Visibility to Work Areas

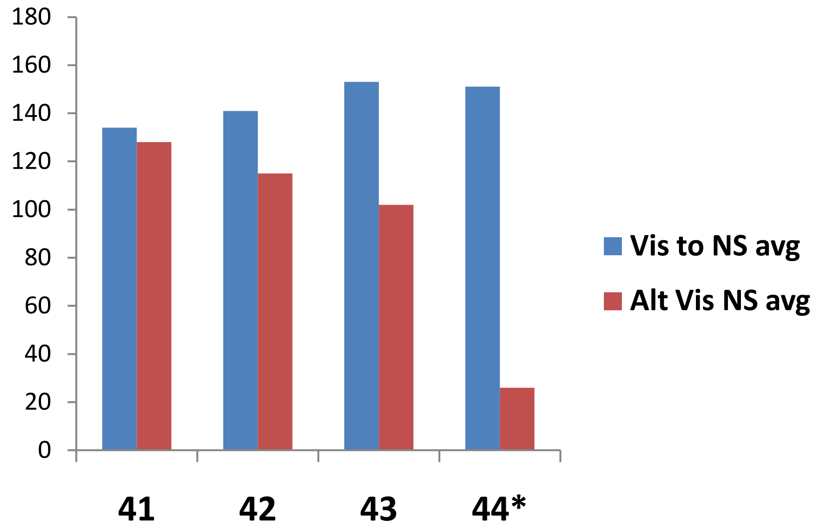


Figure 6.6: Visibility to Nurse Station: Reduced with Alternative
*First segment

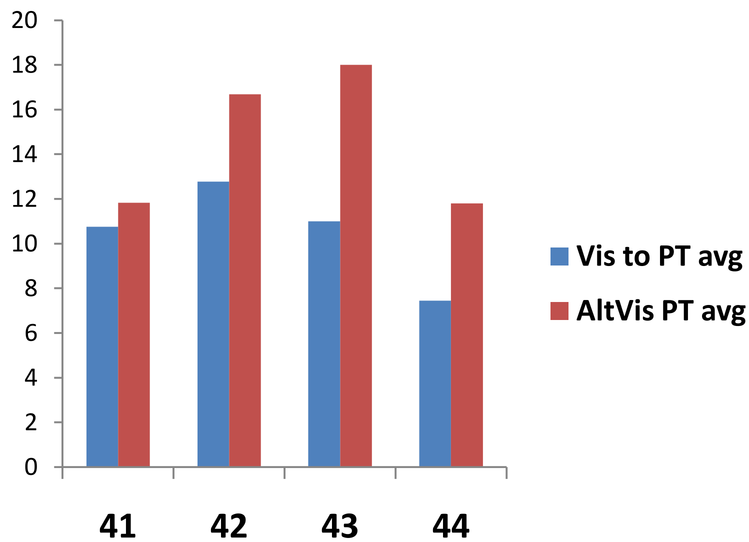


Figure 6.7: Visibility to Patient Bed: Improved with Alternative

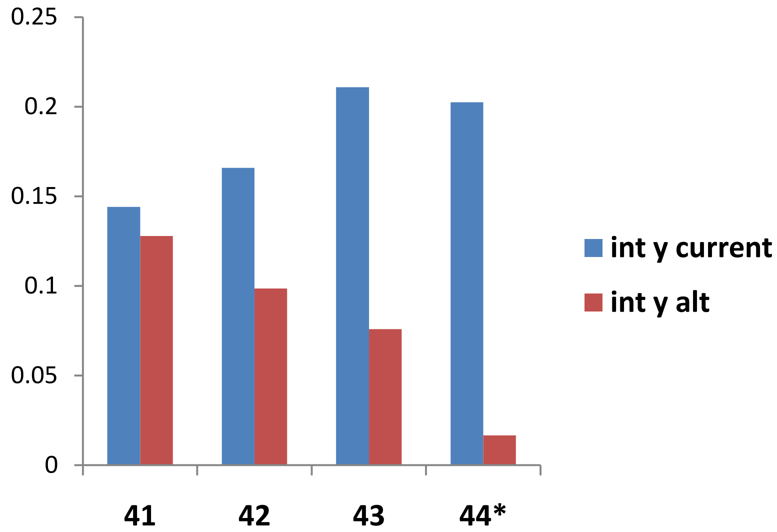


Figure 6.8: Predicted Number of Interruptions by Others: Reduced with Alternative
*First segment

The predicted number of interruptions might be reduced up to 91%, for example, in patient room "44" using the alternative as shown in Figure 6.8. In fact, this may provide more control of the environment for nurses during the task because they might not get interrupted as often as in the existing path but they can always go to nurse station if they want to talk to someone. However, it is hard to judge if this might be one step closer to the similar situation in semi-private space mentioned in Chapter 2, where both privacy and propinquity are supported for informal interactions (Fayard & Weeks, 2007)

If it were proved by further studies that this alternative medication station was effective in reducing the number of interruptions, designers might not put medication stations near the nurses' stations as shown in actual unit examples of Figure 6.9. Placing the medication station away from the central nurse station might require multiple medication stations or storage areas. For example, unit "A" in Figure 6.9 shows four patient rooms as one pod and each pod has a medication station or storage where only 2 nurses might be assigned.

In fact, a design strategy for putting nurse station and medication station together might have been done for operational efficiency. Without considering interruptions, it might have been preferred to have a central location for service and materials so that nurses and others can take care of multiple tasks at the same time or within proximity, saving trips and reducing walking. Supplies, medications, and the nurse station are clustered in almost every wing studied in this thesis.

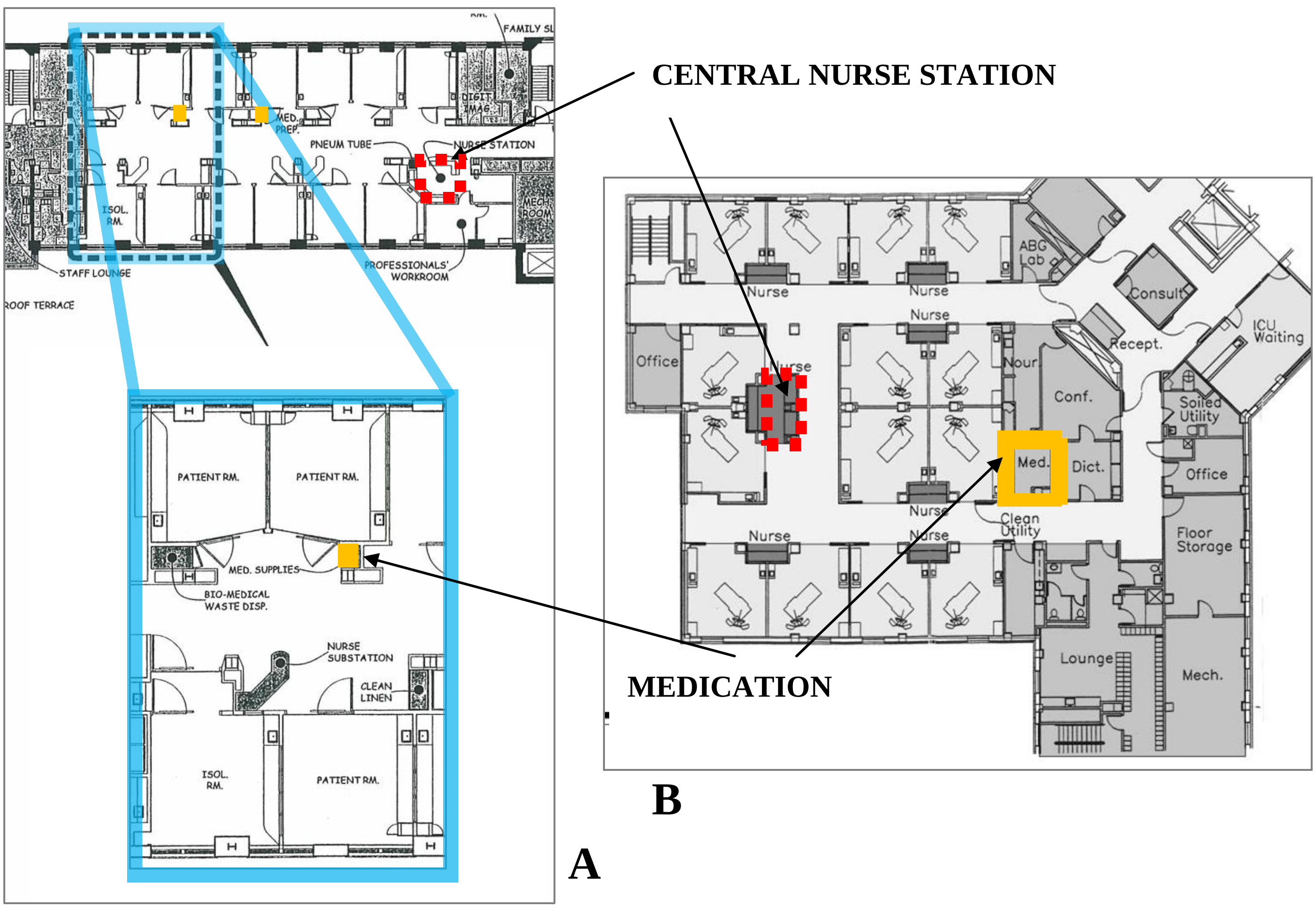


Figure 6.9 Floor Plan Examples: Medication Away from Nurse Station (Image Source: Society of Critical Medicine Award Book 2008)

Additional locations might have the undesirable effect of increasing the cost of equipment and delivery by suppliers and the pharmacy. In addition, the alternative location shown in Figure 6.5 does not have surveillance from central nurse station but only from substations. Further investigation is needed first to verify if multiple medication stations are effective in reducing the number of interruptions, and also to compare the increased cost of multiple stations to the potential savings from reduced interruptions and errors. For implementation, verification of the code requirement is needed if distributed medication storage such as one in unit "A" in Figure 6.9 that might not have surveillance from the central nurse station is allowed in the area of a hospital. The suggested alternative in Figure 6.5 also needs to be reviewed in terms of codes and users for practical feasibility. Another design alternative might be storing medications at bedside to reduce interruptions, but this introduced the problem of interruptions to the medication process from patients and visitors (Biron, Lavoie-Tremblay, et al., 2009) as mentioned in Chapter 3.

6.3 A Test for Effects on the Major Clinical Error

One question we might ask is that "Does making design changes to reduce interruptions really make a difference in the number errors that harm patients?" Since I did not record medication errors, no clear answer is available, but I can make limited conclusions based on other studies that investigated the relationship between errors and interruptions as a test. Westbrook and colleagues (2010) found 115 (2.7%) major clinical errors in total of 4271 medication administrations and that 2266 (53.1%) administrations were interrupted on average. Major errors observed in the study included incidents that are likely to lead to a major permanent loss of function and a permanent reduction in bodily functioning, leading to , for example, increased length of stay or surgical intervention of a patient. The estimated risk of at least one major error during medication administration for a single patient was 2.3% without interruptions and 4.7 % with 4 interruptions based on the model tested to predict the errors:

Table 6.2: Number of Interruptions and Major Error Risk (Westbrook, 2010)

# of Interruptions	Observed Clinical Error Rate (%)	Observed Major Error Rate (%)
0	36.1	2.1
1	43.5	2.8
2	52.7	3.4
3	59.3	5.7

$$l(x) = \text{logit } P\text{ (Major Error)} = -3.7679 + 0.1877\times \text{ Interruptions}$$

where x is the average number of interruptions. For overall clinical errors, one interruption increased the risk by 12.7%; 39.2% without interruptions, 43.6 % with 1 interruption, and 61.3% percent with 5 interruptions.

The predicted number of major errors for patient room “44” with the alternative location was three less than the current location of medication station for 1,000 patients during 10 medication trips. Assuming 5 medications per day per patient, there might be 90 less patients injured with the alternative for a hospital of 400 beds if 60,000 patient days a year were assumed. However, this is a speculation based on a study that was done in a different environment.

These predictions have limitations regarding errors due to differences in physical settings between this thesis and the study mentioned. Westbrook and her colleagues (2010) conducted their study in multiple, non-ICU units such as geriatrics, respiratory medicine, renal/vascular medicine, orthopedic, and neurology in two hospitals while this thesis was done in neurological ICUs. Units of the study had individual patient distribution systems that store medications in locked cabinets at patient bedside but all controlled drugs and injectable medications were stored in the unit medication room. It is not clear how the different setting might have affected the way interruptions and errors happen. However, I speculate that the error rate might have been lower with medications at bedside because medication administration can be done in a relatively short time within the patient room with fewer distractions and interruptions from other activities.

6.4 Strengths and Limitations

This is the first study of this kind that explored the role of the physical environment on interruptions in health care and brings together the knowledge and strengths of studies in architecture, organization, and human factors. The role of the physical environment in interruptions has not been examined by studies in architecture, which has strong methods for measuring spatial configurations for visibility and accessibility, while these architectural methods have not been used in organizational and human factors studies.

In this thesis, I only observed medication trips but not overall activities, and that allowed me to exclude effects of various different tasks that can significantly affect behavior of nurses and made observation efficient. A medication administration trip is relatively standardized process across units and even hospitals, and it is easy to identify the beginning and end of the task as mentioned earlier in Chapter 4. In addition, medication trips might be representative of how interruptions happen for many other activities in the same space, but this is not verified. The likelihood that these results are valid is enhanced by the staffing and patient population in the units studied. These three units are staffed by the same group of nurses who work in all three areas and serve the same group of neurological ICU patients. Patient room assignments are essentially random due to high demand for rooms in these units.

Sample size is relatively small, which is 83 observations for 32 nurses. Comparing the number of interruptions between nurses with segments that are divided by i-partition with visibility to potential work areas in the nurse station and substation did not show a significant difference for interruptions by both self and others. It was close to significance ($p = .070$), and it showed less significance ($p = .123$) for interruptions only by others. However, Poisson regression analysis included nurses as a factor, which should have considered the effects in the analysis.

I examined only a part of the overall picture of the medication administration process. Observation was only done for the return trip to patient rooms because it was not practical for the observer to tell whether nurses were going for medication, for other tasks such as supplies, or merely for communication when they walked away from substations or patient rooms. Interruptions initiated by nurses themselves and those occurring around medication stations were excluded from the analysis. If these are combined, there might have been more interruptions than those initiated by others during return trip of medication administration. In addition, interruptions inside of patient rooms were not observed because the layout was not likely to have effects there, and activities in patient rooms can vary due to the presence of family members or the other care tasks that nurses might work on.

Unfortunately, by observing this specific task, my findings might not be generalized to other activities. However, other activities that involve movement might have similar findings in this thesis because medication administration is a task that is well-known as a task not supposed to be interrupted as mentioned earlier. For people who are sitting, the pattern of interruption might be different perhaps lower, because other people might perceive sitting as working on a task.

In addition, I conducted observations in a single cultural environment for only one specialty and the findings might not be generalized to other settings. Since a limited number of settings were examined, the unit design of this thesis does not represent all the types of units, and findings might have limited implications for certain settings with a different geometry. There were also unique design features in the specific settings chosen to conduct observations. The 2D West and East operated independently but were spatially connected to each other by a wide horizontal hallway as shown in Figure 6.2. This might have affected interruptions. One substation per two patient rooms was used in 2D which might have placed nurses more in the substations than in the nurse station or other locations. The effects of these design features on interruptions were not verified.

6.5 Future Study Directions

Since this is the first study of this kind especially in health care, findings should be confirmed by future studies which might be done in different hospital unit layouts with either the same or different care specialties. Repeated studies are particularly needed in hospitals to verify the role of the physical environment because of the different acuity and conditions of patients. Furthermore, studies that show a relationship between hospital unit design and hospital outcomes such as medication administration errors are needed to increase the awareness of the impact and role of hospital design. I have shown the relationship between the physical environment and interruptions in the particular settings of this thesis but did not demonstrate how the physical environment might affect the errors.

Although I only counted interruptions during the trip from the medication station to a patient room for the analysis, interruptions still happen before and after the trip. There were 37 interruptions around the medication stations overall while 34 during trips and interruptions in patient rooms were not observed. It was outside the scope of this thesis to examine how these interruptions might be different from each other if we categorize interruptions by locations such as around the medication station, during the trip, and in patient rooms. For example, interruptions in one of these locations might matter more than the others for errors. However, this is not verified because studies that examined interruptions and errors often observed the entire medication administration. This might be also affected by where nurses prepare medication: the medication station, nurse station, substation, or patient room, which was not recorded in the previous studies or in this thesis. Therefore, future studies are needed to examine interruptions by different locations and their impact on errors.

Design implications in this thesis would have been more convincing if it could have empirically shown that the alternative location for a medication station reduced the number of interruptions. Even if it is found to be the case, whether savings from a reduced number of interruptions can justify the increased cost of distributed medication stations or medication at bedside should be verified to encourage implementation.

I showed how chance encounters might be differently interpreted as interruptions or interactions, depending on social environment, though a review of the research literature demonstrated the common assumptions that encounters during medication administration were considered interruptions. However, some interruptions might deliver crucial patient information. It was outside the scope of this thesis to examine how valuable the information exchanged during interruptions was, and the examination will clarify whether we should tolerate certain interruptions or not.

In fact, for existing facilities, the most effective way to reduce interruptions and potential errors quickly will be improving awareness of the impact of interruptions. Given that substantial interruptions were conversations of private matters and initiated by nurses themselves, nurses may accept interruptions as routine during their work as mentioned in Chapter 3, but that attitude should be changed at least during critical tasks such as medication administration. This change could come through education and culture modification, which will be more effective when they are accompanied by support of the physical environment.

The role of the physical environment in reducing interruptions might be further examined by future studies beyond the health care and office environments where interruptions have been shown to affect performance. In addition, as mentioned earlier, studies in human factors and health care might examine or consider the role of the physical environment in interruptions and human performance. Since the physical environment might affect and frame the social environment of occupants (Hillier, 1996), the impact of design changes for interruptions might be further investigated in terms of other human responses of the social environment such as satisfaction, stress, and communication.

APPENDIX A: SUMMARY OF STUDIES ON ENCOUNTERS AND THE PHYSICAL ENVIRONMENT

Study and Field (journal)	Social Environment		View on Chance Encounters	Physical Environment		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Allen, 1977; Managing the Flow of Technology. Cambridge, MA: The MIT Press.	7 research and development laboratories	Research and development	Productive	Distance	Probability of weekly communication decreased as distance to communicator reached about 25-30meters and stayed in an asymptotic low level with further distance.		Survey	Did not count how the office is designed
Allen, 1977; An experiment in lab design; Managing the Flow of Technology. Cambridge, MA: The MIT Press.	Before and after move to new facility, 4 groups in a company	Research and development	Productive	Distance and layout change: groups are located together , managers' doors face each other across hallway where group members can access managers	Communication between groups increased as different groups used to be apart came to a location together and within group communication increased with close distance and layout of communication in mind in new facility		Survey	
Allen, 1977; Non-territorial office; Managing the Flow of Technology. Cambridge, MA: The MIT Press.	Product engineers' office	Mediates R&D and production departments	Productive	Traditional office to open plan office without desk assignment	Slightly more distraction after change to open plan non-territorial office	Satisfaction; more privacy in non-territorial office. Sitting certain place (corner) signals privacy needed	Survey	

Study and Field (journal)	Social Environment		View on Chance Encounters	Physical Environment		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Boutellier, 2008. Impact of office layout on communication in a science-driven business R&D Management	R & D of Pharma-ceutical company campus (Novartis)	Research and development Managerial as defined by Zalesny,1987	Productive (including scheduled encounters)	Cell office to multi-space	In multi-space, more short contacts and higher probability of chance encounters but less duration of encounters and less total time spent		Direct observation 5 days for about 2500minutes for each type 61 individuals in multi space floor, 31 in each cell office floor	Observed only selected areas on a floor
Fayard, 2007, Phtocopiers and Water-coolers: The affordance of Informal Interactions, Organizational Studies.	Two research and development firms	2 high-technology firms, Variables included: Position level, job type, uncertainty, task inter-dependence, sociability	Privacy, propinquity, and social designation complement affordance of informal interaction	Function of copier room: Copier, mailbox, fax, printer, bulletin board. Size: appropriate to have multiple people to present and talk but small enough to feel obligated to talk. Geography: Location of place (versus other functions such as office and elevator),	Geography, size, and enclosure. However, theses physical characteristics alone without social characteristics have no clear impact on informal interactions.	Affordance of informal interaction. More people are present in the room with legitimacy is given (everyone needs to make copies) and might result in more interactions	Observation and interview (Qualitative)	

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Fried, 2001, Exploring the relationship between workspace density and employee attitudinal reactions	Large university	93 white-collar employees in a variety of jobs	Counter-productive. Density increases chance of unwanted interactions	Workplace density measured by total number of employees within a radius of 15 feet, no consideration on accessibility and visibility or design.	Only considered density and assumed density increases chance encounters	Organizational commitment, and co-work and job satisfaction. High job complexity and tenure were associated with negative impact of high density	Survey of 93 white-collar employees	Interrup-tions might matter to employee of high job complexity and tenure in high density environment
Hatch, 1987. Physical Barriers, Task Characteristics, and Interaction Activity in Research and Development Firms	Two research and development firms	2 high-technology firms, Variables included: position level, job type, uncertainty, task interdepen-dence, sociability	Both	Partition height, open door time percentage, desk position (face or face away door). More enclosed setting supports interaction of professional-technical workers.	Barriers (#of partitions, partition height, door, desk position, secretary) were positively correlated with interruptions and other types of interactions (see notes)	Interactions of professional-technical workers in research and development firms may be greater in enclosed space than those lacking barrier	Survey of 28 from open-plan and 71 from closed-plan offices	Dependent variables (type of interaction) were: work alone, work together, meetings, interrupt-tions, build relation-ships, phone, breaks

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Lee, 2010, Building and Environment, Office layout affecting privacy, interaction, and acoustic quality in LEED-certified buildings	No description, LEED certified buildings	No description	No direct mention	5 office types: Private, shared enclosed, and open plan with partition 5' or higher, less than 5', or no partition	Sound privacy was better in private office than any other type	Visual privacy, ease of interaction with co-workers, sound privacy	Survey of 3533 workers, secondary data of CBE	

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Oldham, 1995, The Spatial Configuration of Organizations: A Review of the Literature and Some New Research Directions. Research in Personnel and Human Resources Management	Government and non-government office, Univ. Clerical office, Naval ship	Clerical and managerial	Counter productive	Distance, Boundaries, Density, Openness	More unwanted social interactions with less architectural protection (less distance and boundaries, and more density)	Work performance and satisfaction and other	Literature review	
Oldham 1979; Employee Reactions to an Open-Plan Office; Naturally Occurring Quasi-Experiment. Administrative Science	Newspaper organization with 140 full time employee	21 nonsupervisory jobs	Counter productive	Cell office for each department and separated work stations by partitions etc. Open plan with no barrier of more than 3 feet	More interruptions and noise in open plan based on interviews. Ability to concentrate on job decreased significantly in open plan. friendship opportunity also declined in, no significant change for intra and interdepartmental interactions	Internal motivation and satisfaction with work and colleagues declined sharply after moving to open plan office	Before and after survey (76 participants for experiment) with control group (5)	Employees perceived less impact of their work when they could see the entire work process

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Penn, 1999, The space of innovation: interaction and communication in the work environment. Environment and Planning B; Planning and Design	X: Recently privatized energy utility company	No descript-tion on tasks	Productive, Success of company's marketing concept depends on degree of random com-munication	Office layout and measure of integration (accessibility), density with the layout. Both companies intended to increase interaction by design of new buildings with improved accessibility	Significant positive correlation between spatial accessibility and the mean frequency of encounter cited by other business units	Interaction between business units increased by 9%. Meetings are much more unplanned in the new building (from survey, 11% planned and 25% reported unplanned business meetings in the new building)	Question-naire, observa-tion, and floor plan analysis	Every 6 month, they shuffle desk location
	Y: Multidisciplin-ary advertising and marketing agency				Integration affect movement and then movement increases encounters	Trying to maximize innovation through random communication across teams that are organized by project not by discipline.		

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Rashid, 2006, Spatial layout and face-to-face interaction in offices-a study of the mechanism of spatial effect on face-to-face interaction	3 real-estate organiza-tions of the US federal government and 1 clerk’s office of a US district Court	The majority are professionals. In addition, large group of administrative staff and mid-level managers	Productive	Connectivity: Higher value represents the greater number of choice of movement from axial line. Integration: Higher its value, the easier to get to an axial line from all other lines)	Visible copresence predicts (chance and planned) interactions regardless of movement in office spaces. Most interaction occurred in individual workspaces.		Observation, interview	
Rashid, 2009, Space, behavior, and environmental perception in open-plan offices: a prospective study. Environment and Planning B	Government office	Professionals, administrative staff, and managers	Productive	Open-plan somewhat enclosed to open-plan with open workspaces. 20 survey respondents in old office had above eye level partition, 11 below eye level partition. In new office 20 above eye level, and 11 below eye level	People interacted (both planned and by chance) more in new office where accessibility and integration is high. Hallway in new office had less interaction probably because it is exposed to workspaces. Connectivity and integration	Behavior: Movement, interaction, visible copresence. Survey: Privacy, job satisfaction, commitment to organization	Before and after study. Observation and survey (35 in old office and 29 in new office)	Axial line: connec-tivity that means choices of movement from the line; integration that means accessibil-ity of the line.

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	**Task/Job**		**Design Feature and Measure**	**Design Effects on Chance Encounters**			
Sundstrom 1982. Privacy and communica-tion in an open-plan office: A case study. Environmental psychology	Large corpora-tion	Secretarial ; Specialists; Managerial	Counter productive; (The most important component of privacy was the ability to hold confidential conversation)	Secretarial, un-enclosed to one or two 48" partition ; Specialist, double office with door to four 60" partitions; Managerial, private office with door to individual enclosure of 60"-78" partitions	Intrusive speech from neighboring workspaces might have resulted negative ratings of same level of noise in open plan office	Decline in visual and acoustical privacy and satisfaction with communication in open-plan office due to decreased ability to hold confidential conversations especially managerial employees who had private office before	Survey before and after to examine satisfaction with privacy, communica-tions, noise, workspace utility and independent; acoustic measure	Open plan made communica-tion easier in a way but people were satisfied with communicati on in space where they rated as private
Wineman, 2009. Spatial and Social Networks in Organizational Innovation. Environment and Behavior	University	academic research	Productive	Integration (how much accessible), connectivity (how many choices of space to go to), and step-depth (measure spatial distance meaning how many space/rooms need to be passed)	Office layouts that are syntactically integrated (well connected) will promote communication, leading to productive outputs across disciplinary boundaries	Innovation as represented by cross-disciplinary joint-authored publications, and integration was correlated with the innovation.	Analysis of existing data	

STUDY AND FIELD (journal)	SOCIAL ENVIRONMENT		View on Chance Encounters	PHYSICAL ENVIRONMENT		Focused Outcome Measure of the Study	Study Method	Notes
	Type of Setting	Task/Job		Design Feature and Measure	Design Effects on Chance Encounters			
Zalesny, 1987, Traditional versus open offices. Academy of Management Journal	Govern-ment agency	Clerical, professional, and managerial.	No mention Clerical had similar accessibility in both settings but panels demarcated their space in new setting	Move from private and partial open to open plan office	Number of Information requests (not exclusively chance encounters) received decreased with move for managerial and professional while it increased for clerical	Privacy and job satisfaction, information request frequency. Perceived privacy was lower after move except clerical employees who felt more privacy.	Before and after survey of 426 employees	New setting had more attractive appearan ce than old setting.

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